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NETWORK MANAGEMENT POLICY FOR OVERLAPPING BETWEEN CABLING AND WIRELESS NETWORKS IN MEDICARE SYSTEM

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When the network utilization increased, congestion and delay problems occurred. Then, the network cannot properly serve needs of users. Since the Medicare system has significant applications transmitted within the system, these problems can be critically serious in some emergency cases. Consequently, Overlap-network with policies model was proposed in this Thesis. The results have shown that with the appropriate management of transmitted applications through a network policy as well as determining of resource allocation by installing a wireless network over the original wired network can efficiently enhance performance by relieving the congestion and delay problems. Therefore, this research has successfully proved that Overlap-network with policies is the efficient solution with cost-effectiveness on the network management policy for the Medicare system.

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CHAPTER I

INTRODUCTION

This chapter is firstly states the interested problem in Section 1.1, and then the objective is described in Section 1.2. In Section 1.3, the scope and constraint of this Thesis will be discussed followed by definition of technical terms in Section 1.4. Additionally, benefit of Thesis is mentioned in Section 1.5, and this entire Thesis is also outlined in Section 1.6.

1.1 Problem Statement

Hospital services are significantly important because of human's lives. Thus, these services require an appropriate network management system for transferring data. At present, each medical organization, or a healthcare organization, uses a cabling system as a backbone network for transmitting their information, such as UTP, and fiber optics. This legacy system has been implemented for decades before wireless comes to lives. Currently, the wireless network also plays an important role in the data transfer system. Consequently, many medical organizations or hospitals tend to install and deploy a wireless network (IEEE 802.11—Wi-Fi) as an alternative network for supporting the network utilization in their organizations. Thus, applications of this wireless network are to transmit general information without concerning of the security issue. For instance, hospitals provide Internet services for patients and their relatives while they are waiting for the diagnosis, or recuperation. As a result, the healthcare organization implemented a cabling system as a backbone or core network to serve the main purpose of their hospital with a capability of authentication and authorization, and also implemented a wireless network, which excludes for the backbone network, as an alternative network to provide minor purpose of their hospitals, such as Internet services for their patients.

As a result of network installation, various kinds of medical information can be transmitted to the destination in a few second. Thus, the ability of medical diagnostic is increasing. For instance, Laboratory Department can transmit a patient's information, such as pictures, voice, and video to a doctor room for enhancing a performance and comfort of diagnosis, or medical records can be transmitted between departments within the hospital, such as from the Administration Department to a doctor's room etc. Due to various kinds of services and applications which are served for several purposes within the network, congestion, an unavoidable problem, occurs. Therefore, incoming information may delay in some situations. In contrast, hospital services are sometimes significantly in vital so that this problem can be a serious one in some emergency cases.

From above, network administrators will solve these problems by creating a new performance network system, or expanding a core network. In doing so, they generally expand the existing cabling system as it is easier than other alternatives. Although they can obtain a reliable authentication and authorization of their information, it will cost a lot of money and implementation time. Furthermore, the old network system must be terminated and replaced by the new one iteratively.

Since Medicare system consists of various types of data, including critical data that causes life and dead of patients, thus, the transferring system can be counted as the delay sensitive system. Additionally, the transferring system must be reliable. For that reason, this research emphasizes on the Medicare system, that originally implemented with the cabling system, with the overlapping wireless system for cost saving. Under this new architecture, the network must also be well-managed with a good policy; otherwise, all sensitive data will be affected by bad management and cause vital damage to patients' lives. Accordingly, this situation requires an improvement of a core network by installing a wireless network with a suitable network management policy in Medicare system. Then, this Thesis has an aim to propose a suitable network management policies that are efficient to manage the overlapping among wired and wireless networks under low cost of investment and maintenance, as well as maintaining scalability for the organization.

1.2 Objective

This Thesis focuses on improvement of an overlapping between cabling and wireless networks in Medicare system using network management policy. The objective of this Thesis is to prescribe the network management policies for transmitting medical information on Overlap-network efficiently. In addition, it will further evaluate performance of this Overlap-network with policies comparing with another kind of network architectures and management policies.

1.3 Scope of Thesis and Constraint

Since hospital service is very essential in vital, this Thesis emphasized on improvement of Medicare system using appropriate network management policies for the overlapping among cabling and wireless networks. Setting up these network management policies is not only used for Medicare system properly, but also can be further applied to systems in any kinds of organizations.

There are various methods for measuring a network performance, such as real implementation, calculation, and simulation. As the fact that the real implementation is hard to apply because many factors must be fixed to measure the performance efficiently. Additionally, it is time consuming and cost effective. Especially, the real system must be temporarily terminated in order to evaluate the performance of overall network. To overcome this problem, an accepted network simulation tool, which is Qualnet, will be used in this Thesis. Consequently, a real network system used in a hospital will be simulated by Qualnet for evaluating a performance of the system.

In this experiment, information is transmitted over the entire system without consideration of its authentication and authorization, in order to simplify a system as well as paying an attention to the impacts of the applied policies. Therefore, all network architectures in this Thesis are simulated by excluding the security issue. Additionally, flows of the wired networks in all network models are represented only the routine work in the Medicare system, while the flows of wireless networks are categorized according to the objectives and user types. Thus, the suitable network management policies for the wired and the wireless networks are determined differently, which the wired policies are determined by an important of routine works while the wireless policies are considered by the objectives and user types. Consequently, the wired and the wireless policies are performed independently.

1.4 Definition

Network Management Policy: Policies that used to plan, implement, maintenance, and control all activities and resources within a network for satisfying services with cost-effectiveness.

Quality of Service (QoS): the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow.

Throughput: a measure of how fast we can actually send data through a network.

Latency (Delay): it defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

1.5 Benefits

This Thesis proposed an alternative network architecture, which is the overlapping between cabling and wireless networks, to solve the stated problems. Implementation of the Overlap-network can obtain low cost of investment, reduced implementation time, and easy for maintenance. Furthermore, the suitable network management policies are also applied to this Overlap-network to enhance a performance of medical information transmission.

In the proposed policies, transmitted medical information is appropriately preceded by considering an important of flow in each network. Thus, it can mitigate congestion occurred in communication channel and delay problems in addition to serve for several purposes of users properly.

Moreover, the performance of the entire system is improved as well as the transmission of significant information due to well-managed of each flow in network system. Especially, the system can perform its vital services to user requirements in time, in spite of occurring congestion in communication channel.

1.6 Outline of the Thesis

The rest of Thesis is organized as follows. In Chapter 2, it provides the fundamental knowledge and the literature review for this Thesis. Then, Chapter 3 describes Network architectures and proposed policies followed by showing the experimental results and the discussion in Chapter 4. Finally, conclusions are drawn in Chapter 5.

CHAPTER II

FUNDAMENTAL KNOWLEDGE AND LITERATURE REVIEW

In this chapter, it will provide fundamental knowledge and literature review for this Thesis. Thus, performance, performance mechanisms, Gigabit Ethernet, Wireless LAN (IEEE 802.11), Asynchronous Transfer Mode (ATM), and Quality of service is described in Section 2.1 to Section 2.6 respectively. In addition, some related work is reviewed in Section 2.7.

2.1 Performance

Performance is the set of levels for capacity, delay, and RMA (reliability, maintainability, and availability) in a network. It is usually desirable to optimize these levels, either for all (users, applications, and devices) traffic flows in the network, or for one or more sets of traffic flows, based on groups of users, applications, and/or devices.

In supporting of performance in a network, a performance architecture must be considered. The performance architecture is the set of performance mechanisms to configure, operate, manage, provision, and account for resources in the network that support traffic flows.

The performance architecture [48] describes how users, applications, devices, and (existing) network requirements for performance (capacity, delay, and RMA [reliability, maintainability, and availability]) will be met within the planned network.

An important part of developing this architecture is to determine the performance goals for the network. For example, performance may be applied to:

• Improve the overall performance of the network (e.g., to improve response times and throughput to all users, regardless of where they are and what they are doing)

• Support a particular group or groups of users or applications, maybe new or planned applications

• Control resource allocation for accounting, billing, and/or management purposes

In general, performance consists of one or more of the following: controlling traffic inputs to the network (admission and rate controls); adjusting the baseline performance of the network (traffic or capacity engineering); controlling all or part of the network for delivery of specific services (prioritizing, scheduling, and conditioning traffic flows); and implementing a feedback loop to users, applications, devices, and management to modify controls as necessary.

2.2 Performance Mechanisms

Performance mechanisms [48] discussed here are quality of service, resource control (prioritization, traffic management, scheduling, and queuing), service-level agreements, and policies. Subsets of these mechanisms are usually used together to form a comprehensive approach to providing single-tier and multi-tier performance in a network. These mechanisms provide the means to identify traffic flow types, measure their temporal characteristics, and take various actions to improve performance for individual flows, groups of flows, or for all flows in the network.

2.2.1 Quality of Service: DiffServ and IntServ

Quality of Service, or QoS, is determining, setting, and acting upon priority levels for traffic flows. QoS is usually applied to define a class of mechanisms that provision and apply priority levels in multiple layers in the network. This class includes IP QoS (including MPLS), type of service (ToS), and Frame Relay committed information rate (CIR).

For IP-based traffic, there are two standard types of QoS: differentiated services (DiffServ, or DS) and integrated services (IntServ, or IS)

• *DiffServ*

It approaches QoS from the perspective of aggregating traffic flows on a per-hop basis based on traffic behavior. In DiffServ, IP packets are marked in the type of service (ToS) byte for IPv4 or in the traffic class byte in IPv6 so that they will receive the corresponding performance at each network device (or hop). DiffServ defines a set of values (termed differentiated services code points, or DSCPs) for classes of traffic flows, to be used by resource control mechanisms. An important concept of DiffServ is that it applies to ***aggregates*** of traffic flows (e.g., composite flows), not individual traffic flows. The main reason for this is for scalability (particularly across the Internet, but it could also be applied in a large enterprise environment). If, in a network architecture and design, all flows requiring priority service were treated individually, one trade-off in the network would be the amount of resources (e.g., memory in network devices) required to store and maintain state information for each individual flow across the network. This resource requirement grows geometrically with the network and therefore does not scale well. By aggregating flows into traffic classes, storing and maintaining state information become more tenable.

• *IntServ*

It approaches QoS from the perspective of supporting traffic flows on an individual, end-to-end basis. It defines values and mechanisms for allocating resources to flows across the end-to-end path of the flow. The advantages of IntServ come at a price. IntServ requires support on network devices across the flow travels, and it requires resources (e.g., memory, processing, and bandwidth) for each flow. IntServ also requires a mechanism to communicate flow requirements, as well as the setup and teardown of resource allocations, across network devices in the end-to-end path of a flow. Such signaling is usually provided by the resource reservation protocol (RSVP). This protocol is used by network devices (including user devices) to request specific quality of service levels from network devices in the end-to-end path of a traffic flow. Successful RSVP requests usually result in resources being reserved at each network device along this end-to-end path, along with state information about the requested service.

2.2.2 Resource control

Resource control (Prioritization, traffic management, scheduling, and queuing) are at the heart of providing performance in a network. A performance architecture may include one or more of these mechanisms, in conjunction with QoS, SLAs, and policies, to provide performance to its users, applications, devices, and traffic flows. These mechanisms are usually implemented in network devices, such as routers and switches, but can also be applied to the network as stand-alone hardware, such as in vendor-specific admission control and traffic management devices.

• ***Prioritization***

Prioritization is the process of determining users, applications, devices, flows, or connections gain services ahead of others, or gain higher level of services. Prioritization is necessary as there will be competition between traffic flows for network resources. With a limited amount of resources available in any networks, prioritization determines the order of users to access resources, including their authorities.

According to the performance architecture, there are two high-level views of performance: single-tier and multi-tier performance. The single-tier performance architecture is the architecture that capacity, delay, and/or RMA are optimized for all traffic flows; on the other hand, the multi-tier performance architecture considers capacity, delay, and/or RMA for one or more groups of traffic flows, based on groups of users, applications, and/or devices. Either or both of these views can be taken for a network architecture.

Prioritization is ranking (determining a priority level) based on importance and urgency. Ranking may be applied to users, applications, devices, or their traffic flows. A rank or priority level indicates the importance and/or urgency of that users, applications, devices, or flows, relative to other users, applications, devices, or flows in that network. Such priority levels are often determined during the requirements and flow analyses.

Priority levels may be based on the type of protocol (e.g., TCP versus UDP), service, or port number, by IP or MAC-layer address, or by other information embedded within the traffic. This information can be maintained in databases and coupled with policies and SLAs as part of the performance architecture.

Priority levels are used by network devices to help determining the traffic flows whether it will be allowed on the network (admission control), scheduling of traffic flows onto the network, and conditioning of flows throughout the network.

- ***Traffic Management***

Traffic management consists of admission control and traffic conditioning. Admission control is the ability to refuse access to network resources. Traffic conditioning is a set of mechanisms that modify (increase or decrease) performance to traffic flows, as a precursor to scheduling.

Admission control uses priority levels to change the behavior of network access. In a best-effort network without admission control, access to the network is democratic in that all traffic flows have more or less equal chances to access network resources. With the admission control, however, access is permitted, denied, or sometimes delayed, based on the relative priority of that traffic. An example of this is assigning a higher priority to real-time traffic flows, such as voice and video. In this case voice and video traffic flows are given access before other traffic flows. When network resources dedicated to these flows are fully utilized, further flows are refused (blocked). Admission control is most often applied at access areas.

• *Scheduling*

Once traffic has been prioritized and conditioned, it is forwarded to one or more output queues for transmission onto the network. Scheduling is the mechanism that determines the order in which traffic is processed for transmission. Scheduling uses priority levels to determine which traffic flows get processed first and most often.

Scheduling is applied at network devices throughout a network. In most network devices, such as switches and routers, scheduling is provided through network management, or as part of the QoS implementation in that device.

Scheduling may be proprietary (enterprise-specific) or standards-based. Some commonly used standard scheduling algorithms include weighted fair queuing (WFQ) and class-based queuing (CBQ). These algorithms provide some degree of fairness in queuing while allowing relative priority levels (weights).

The combination of QoS, prioritization, traffic management, and scheduling provides a comprehensive set of mechanisms that can be applied across a network to achieve various performance levels for traffic flows.

• *Queuing*

Queuing is storing IP packets (this can also be applied to frames or cells) within a network device while they wait for processing. There may be several locations where packets are stored (queues) within a network device, for each type of processing that the device is performing on each packet (e.g., holding packets received from the network, processing for QoS, holding packets for transmission onto the network).

There are a number of queuing mechanisms available in network devices. The standard queuing mechanisms are illustrated as follow:

First in first out (FIFO) queuing is arguably the simplest queuing mechanism available. In FIFO queuing packets are stored in a single queue. For an output FIFO queue, packets are transmitted onto the network in the order that they were received (at the input queue).

In class-based queuing (CBQ), multiple queues with differing priorities are maintained. Priority levels are configurable in the network device and indicate the performance levels required for each traffic type. Packets of each priority level are placed in their respective queues. Higher-priority queues are processed before lower-priority queues, with the result that higher-priority traffic receives more network resources and thus greater performance.

Like CBQ, **weighted fair queuing (WFQ)** assigns priorities (weights) to queues. Typically with this mechanism, high-priority traffic flows are processed first, and lower-priority traffic flows share the remaining resources.

Generally, when a queue becomes full (e.g., during periods of congestion), packets are dropped either from the beginning of the queue (head) or end of the queue (tail). In either case, the dropping of these packets is likely to be unfair to one or a few traffic flows. As a result, **random early detect (RED)** was developed to randomize the packet dropping process across a queue. In addition, RED will drop packets early (before the queue is actually full) to force traffic flows (i.e., TCP flows) to adjust by reducing their transmission rate.

Weighted RED (WRED) operates in the same fashion as RED but supports multiple priority levels (one for each queue) for dropping packets.

2.2.3 Service-Level Agreements

Service-level agreements, or SLAs, are (typically) formal contracts between a provider and user that define the terms of the provider's responsibility to the user and the type and extent of accountability if those responsibilities are not met. While SLAs have traditionally been contracts between service providers (e.g., ISPs) and their customers, this concept can also be applied to the enterprise environment.

SLA performance elements may be as simple as a data rate (minimum, peak) and burst tolerance (size, duration), and can be separated into upstream (in the direction from the destination to the source) and downstream (in the direction from the source to the destination).

2.2.4 Policies

Policies are formal or informal sets of high-level statements and rules about how network resources (and, therefore, performance) are to be allocated among users. They are used to create and manage one or more performance objectives. Policies complete the framework of performance for a network by coupling the high-level (e.g., management) view of how the network should perform, with mechanisms to implement performance at the network devices (QoS) and feedback loops with users (SLAs).

Policies may describe what network, computing, storage, or other resources are available to users, when resources are available, or which users are permitted to access certain resources. In this sense these policies are similar to policies for security or routing.

Policy information is often implemented, stored, and managed in policy databases kept on the network. Policy information is passed between databases and network devices using Common Open Policy Service (COPS) and Lightweight Directory Access Protocol (LDAP).

2.3 Gigabit Ethernet

The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). The IEEE committee calls the Standard 802.3z. The goals of the Gigabit Ethernet [49] design can be summarized as follows:

1. Upgrade the data rate to 1 Gbps.

2. Make it compatible with Standard or Fast Ethernet.

3. Use the same 48-bit address.

4. Use the same frame format.

5. Keep the same minimum and maximum frame lengths.

6. To support autonegotiation as defined in Fast Ethernet.

2.3.1 MAC Sublayer

A main consideration in the evolution of Ethernet was to keep the MAC sublayer untouched. However, to achieve a data rate 1 Gbps, this was no longer possible. Gigabit Ethernet has two distinctive approaches for medium access: half-duplex and full-duplex.

• ***Full-Duplex Mode***

In the full-duplex mode, there is a central switch connected to all computers or other switches. Under this mode, each switch has buffers for each input port in which data are stored until they are transmitted. There is no collision in this mode. This means that CSMA/CD is not used. Lack of collision implies that the maximum length of the cable is determined by the signal attenuation in the cable, not by the collision detection process.

• ***Half-Duplex Mode***

The Gigabit Ethernet can also be used in the half-duplex mode, although it is rare. In this case, a switch can be replaced by a hub, which acts as the common cable in which a collision might occur. The half-duplex approach uses CSMA/CD. However, the maximum length of the network in this approach is totally depended on the minimum frame size. Three methods have been defined: traditional, carrier extension, and frame bursting.

In the traditional approach, the minimum length of the frame was kept as in traditional Ethernet (512 bits) and the slot time for Gigabit Ethernet is 512 bits x 1/1000 gs, which is equal to 0.512 gs. To allow for a longer network, the minimum frame length was increase. The carrier extension approach defines the minimum length of a frame as 512 bytes (4096 bits). Thus, the maximum length of the network can be increased 8 times to a length of 200 m. This allows a length of 100 m from the hub to the station. The last approach is the frame bursting. This approach was proposed to improved efficiency of sending short frames with redundant data. This technique sent multiple frames that look alike one frame with padding between frames.

2.3.2 Physical Layer

The physical layer in Gigabit Ethernet is more complicated than that in Standard or Fast Ethernet. Some features of this layer were briefly discussed.

• *Topology*

Gigabit Ethernet is designed to connect two or more stations. If there are only two stations, they can be connected point-to-point. Three or more stations need to be connected in a star topology with a hub or a switch at the center.

• *Implementation*

Gigabit Ethernet can be categorized as either a two-wire or a four-wire implementation. The two-wire implementations use fiber-optic cable (1000Base-SX, short-wave, or 1000Base-LX, long-wave), or STP (1000Base-CX). The four-wire version uses category 5 twisted-pair cable (1000Base-T).

• *Encoding*

Gigabit Ethernet cannot use the Manchester encoding scheme because it involves a very high bandwidth (2 GBaud). The two-wire implementations use an NRZ scheme, but NRZ does not self-synchronize properly. To synchronize bits, particularly at this high data rate, 8B/10B block encoding is used.

This block encoding prevents long sequences of 0s or 1s in the stream, but the resulting stream is 1.25 Gbps. Note that in this implementation, one wire (fiber or STP) is used for sending and one for receiving.

In the four-wire implementation it is not possible to have 2 wires for input and 2 for output, because each wire would need to carry 500 Mbps, which exceeds the capacity for category 5 UTP. As a solution, 4D-PAM5 encoding is used to reduce the bandwidth. Thus, all four wires are involved in both input and output; each wire carries 250 Mbps, which is in the range for category 5 UTP cable.

2.4 Wireless LAN (IEEE 802.11)

Wireless communication [49] is one of the fastest-growing technologies. The demand for connecting devices without the use of cables is increasing everywhere. Wireless LANs can be found on college campuses, in office buildings, and in many public areas.

IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data link layers.

2.4.1 Architecture

The standard defines two kinds of services: the basic service set (BSS) and the extended service set (ESS).

• ***Basic Service Set***

IEEE 802.11 defines the basic service set (BSS) as the building block of a wireless LAN. A basic service set is made of stationary or mobile wireless stations and an optional central base station, known as the access point (AP).

The BSS without an AP is a stand-alone network and cannot send data to other BSSs. It is called an ***ad hoc architecture***. In this architecture, stations can form a network without the need of an AP; they can locate one another and agree to be part of a BSS. A BSS with an AP is sometimes referred to as an ***infrastructure network.***

• *Extended Service Set*

An extended service set (ESS) is made up of two or more BSSs with APs. In this case, BSSs are connected through a distribution system, which is usually a wired LAN. The distribution system connects the APs in the BSSs. IEEE 802.11 does not restrict the distribution system; it can be any IEEE LANs, such as an Ethernet.

The extended service set uses two types of stations: mobile and stationary. The mobile stations are normal stations inside a BSS. The stationary stations are AP stations that are part of a wired LAN. When BSSs are connected, the stations within reach of one another can communicate without the use of an AP. However, communication between two stations in two different BSSs usually occurs via two APs.

• *Station Types*

IEEE 802.11 defines three types of stations based on their mobility in a wireless LAN: no-transition, BSS-transition, and ESS-transition mobility. A station with no-transition mobility is either stationary (not moving) or moving only inside a BSS. A station with BSS-transition mobility can move from one BSS to another, but the movement is confined inside one ESS. A station with ESS-transition mobility can move from one ESS to another. However, IEEE 802.11 does not guarantee that communication is continuous during the move.

2.4.2 MAC Sublayer

IEEE 802.11 defines two MAC sublayers: the distributed coordination function (DCF) and point coordination function (PCF). The details of each sublayer are described as follows.

• *Distributed Coordination Function (DCF)*

DCF uses CSMA/CA as the access method to protect the collision over the communication channel.

• *Point Coordination Function (PCF)*

The point coordination function (PCF) is an optional access method that can be implemented in an infrastructure network (not in an ad hoc network). It is implemented on top of the DCF and is used mostly for time-sensitive transmission.

PCF has a centralized, contention-free polling access method. The AP performs polling for stations that are capable of being polled. The stations are polled one after another, sending any data they have to the AP.

To give priority to PCF over DCF, another set of interframe spaces has been defined: PIFS and SIFS. The SIFS is the same as that in DCF, but the PIFS (PCF IFS) is shorter than the DIFS. This means that if, at the same time, a station wants to use only DCF and an AP wants to use PCF, the AP has priority.

• *Fragmentation*

The wireless environment is very noisy; a corrupt frame has to be retransmitted. The protocol, therefore, recommends fragmentation--the division of a large frame into smaller ones. It is more efficient to resend a small frame than a large one.

• *Frame Format*

The MAC layer frame consists of six types of nine fields, as described below.

1) Frame control (FC). The FC field is 2 bytes long and defines the type of frame and some control information.

2) D. In all frame types except one, this field defines the duration of the transmission that is used to set the value of NAV. In one control frame, this field defines the ID of the frame.

3) Addresses. There are four address fields, each 6 bytes long. The meaning of each address field depends on the value of the To DS and From DS subfields.

4) Sequence control. This field defines the sequence number of the frame to be used in flow control.

5) Frame body. This field, which can be between 0 and 2312 bytes, contains information based on the type and the subtype defined in the FC field.

6) FCS. The FCS field is 4 bytes long and contains a CRC-32 error detection sequence.

• *Frame Types*

A wireless LAN defined by IEEE 802.11 has three categories of frames:

Management Frames: Management frames are used for the initial communication between stations and access points.

Control Frames: Control frames are used for accessing the channel and acknowledging frames.

Data Frames: Data frames are used for carrying data and control information.

2.4.3 Addressing Mechanism

The IEEE 802.11 addressing mechanism specifies four cases, defined by the value of the two flags in the FC field, To DS and From DS. Each flag can be either 0 or 1, resulting in four different situations. The interpretation of the four addresses (address 1 to address 4) in the MAC frame depends on the value of these flags, as described below.

Case 1:00 In this case, the frame is not going to a distribution system (To DS = 0) and is not coming from a distribution system (From DS = 0). The frame is going from one station in a BSS to another without passing through the distribution system. The ACK frame should be sent to the original sender.

Case 2:01 In this case, the frame is coming from a distribution system (From DS = 1). The frame is coming from an AP and going to a station. The ACK should be sent to the AP.

Case 3:10 In this case, the frame is going to a distribution system (To DS = 1). The frame is going from a station to an AP. The ACK is sent to the original station.

Case 4:11 In this case, the distribution system is also wireless. The frame is going from one AP to another AP in a wireless distribution system. if the distribution system is a wired LAN, defining address is unnecessary.

2.4.4 Physical Layer

This section will describe six specifications in the physical layer of the wireless that are currently implemented: IEEE802.11 FHSS, IEEE802.11DSSS, IEEE802.11 Infrared, IEEE802.11a OFDM, IEEE802.11b DSSS, and IEEE802.11g OFDM.

• ***IEEE 802.11 FHSS***

IEEE 802.11 FHSS uses the frequency-hopping spread spectrum (FHSS) method. FHSS uses the 2.4-GHz ISM band. The band is divided into 79 subbands of 1 MHz (and some guard bands). A pseudorandom number generator selects the hopping sequence. The modulation technique in this specification is either two-level FSK or four-level FSK with 1 or 2 bits/baud, which results in a data rate of 1 or 2 Mbps.

• *IEEE 802.11 DSSS*

IEEE 802.11 DSSS uses the direct sequence spread spectrum (DSSS) method. DSSS uses the 2.4-GHz ISM band. The modulation technique in this specification is PSK at 1 Mbaud/s. The system allows 1 or 2 bits/baud (BPSK or QPSK), which results in a data rate of 1 or 2 Mbps.

• *IEEE 802.11 Infrared*

IEEE 802.11 infrared uses infrared light in the range of 800 to 950 nm. The modulation technique is called pulse position modulation (PPM). For a 1-Mbps data rate, a 4-bit sequence is first mapped into a 16-bit sequence in which only one bit is set to 1 and the rest are set to 0. For a 2-Mbps data rate, a 2-bit sequence is first mapped into a 4-bit sequence in which only one bit is set to 1 and the rest are set to 0. The mapped sequences are then converted to optical signals; the presence of light specifies 1, the absence of light specifies 0.

• *IEEE 802.11a OFDM*

IEEE 802.11a OFDM describes the orthogonal frequency-division multiplexing (OFDM) method for signal generation in a 5-GHz ISM band. OFDM is similar to FDM, with one major difference: All subbands are used by one source at a given time. Sources contend with one another at the data link layer for access. The band is divided into 52 subbands, with 48 subbands for sending 48 groups of bits at a time and 4 subbands for controlled information. The scheme is similar to ADSL. Dividing the band into subbands diminishes the effects of interference. If the subbands are used randomly, security can also be increased. OFDM uses PSK and QAM for modulation. The common data rates are 18 Mbps (PSK) and 54 Mbps (QAM).

• *IEEE 802.11b DSSS*

IEEE 802.11b DSSS describes the high-rate direct sequence spread spectrum (HR-DSSS) method for signal generation in the 2.4-GHz ISM band. HR-DSSS is similar to DSSS except for the encoding method, which is called complementary code keying (CCK). CCK encodes 4 or 8 bits to one CCK symbol. To be backward compatible with DSSS, HR-DSSS defines four data rates: 1, 2, 5.5, and 11 Mbps. The first two use the same modulation techniques as DSSS. The 5.5-Mbps version uses BPSK and transmits at 1.375 Mbaud/s with 4-bit CCK encoding. The 11-Mbps version uses QPSK and transmits at 1.375 Mbps with 8-bit CCK encoding.

• *IEEE 802.11g*

This new specification defines forward error correction and OFDM using the 2.4-GHz ISM band. The modulation technique achieves a 22- or 54-Mbps data rate. It is backward-compatible with 802.11b, but the modulation technique is OFDM.

2.5 Asynchronous Transfer Mode (ATM)

Asynchronous Transfer Mode [49] is the **cell relay** protocol designed by the ATM Forum and adopted by the ITU-T. In fact, ATM can be thought of as the "highway" of the information superhighway.

2.5.1 Design Goals

There are six challenges for designing of ATM, as described below.

1. Foremost is the need for a transmission system to optimize the use of high-data-rate transmission media, in particular optical fiber. In addition to offering large bandwidths, newer transmission media and equipment are dramatically less susceptible to noise degradation. A technology is needed to take advantage of both factors and thereby maximize data rates.

2. The system must interface with existing systems and provide wide-area interconnectivity between them without lowering their effectiveness or requiring their replacement.

3. The design must be implemented inexpensively so that cost would not be a barrier to adoption. If ATM is to become the backbone of international communications, as intended, it must be available at low cost to every user who wants it.

4. The new system must be able to work with and support the existing telecommunications hierarchies (local loops, local providers, long-distance carriers, and so on).

5. The new system must be connection-oriented to ensure accurate and predictable delivery.

6. Last but not least, one objective is to move as many of the functions to hardware as possible (for speed) and eliminate as many software functions as possible (again for speed).

2.5.2 Problems

Before discussion of the solutions to these design requirements, it is useful to examine some of the problems associated with existing systems.

• *Frame Networks*

Before ATM, data communications at the data link layer had been based on frame switching and frame networks. Different protocols use frames of varying size and intricacy. As networks become more complex, the information that must be carried in the header becomes more extensive. The result contains larger and larger headers relative to the size of the data unit. In response, some protocols have enlarged the size of the data unit to make header use more efficient (sending more data with the same size header). Unfortunately, large data fields create waste. If there is not much information to transmit, much of the field goes unused. To improve utilization, some protocols provide variable frame sizes to users.

• *Mixed Network Traffic*

It is the fact that the variety of frame sizes makes traffic unpredictable. Switches, multiplexers, and routers must incorporate elaborate software systems to manage the various sizes of frames. A great deal of header information must be read, and each bit counted and evaluated to ensure the integrity of every frame. Internetworking among the different frame networks is slow and expensive at best, and impossible at worst.

Another problem is that of providing consistent data rate delivery when frame sizes are unpredictable and can vary so dramatically. To get the most out of broadband technology, traffic must be time-division multiplexed onto shared paths no matter what sizes of the frames are.

• *Cell Networks*

Many problems associated with the frame internetworking are solved by adopting a concept called cell networking. A cell is a small data unit of fixed size. In a **cell network**, which uses the **cell** as the basic unit of data exchange, all data are loaded into identical cells that can be transmitted with complete predictability and uniformity. As frames of different sizes and formats reach the cell network from a tributary network, they are split into multiple small data units of equal length and are loaded into cells. The cells are then multiplexed with other cells and routed through the cell network. Because each cell is the same size and all are small, the problems associated with multiplexing different-sized frames are avoided.

A second point in this same scenario is that the high speed of the links coupled with the small size of the cells means that, despite interleaving, cells from each line arrive at their respective destinations in an approximation of a continuous stream (much as a movie appears to your brain to be continuous action when in fact it is really a series of separate, still photographs). In this way, a cell network can handle real-time transmissions, such as a phone call, without the parties being aware of the segmentation or multiplexing at all.

• *Asynchronous TDM*

ATM uses asynchronous time-division multiplexing to multiplex cells coming from different channels. It uses fixed-size slots (size of a cell). ATM multiplexers fill a slot with a cell from any input channel that has a cell; the slot is empty if none of the channels has a cell to send.

2.5.3 Architecture

ATM is a cell-switched network. Users access devices, called endpoints, are connected through a user-to-network interface (UNI) to the switches inside the network. The switches are connected through network-to-network interfaces (NNIs).

• *Virtual Connection*

Connection between two endpoints is accomplished through transmission paths (TPs), virtual paths (VPs), and virtual circuits (VCs). A transmission path (TP) is the physical connection (wire, cable, satellite, and so on) between an endpoint and a switch or between two switches. A transmission path is divided into several virtual paths. A virtual path (VP) provides a connection or a set of connections between two switches. Additionally, cell networks are based on virtual circuits (VCs). All cells belonging to a single message follow the same virtual circuit and remain in their original order until they reach their destination.

Identifiers In a virtual circuit network, to route data from one endpoint to another, the virtual connections need to be identified. For this purpose, the designers of ATM created a hierarchical identifier with two levels: **a virtual path identifier (VPI)** and **a virtual-circuit identifier (VCI)**. The VPI defines the specific VP, and the VCI defines a particular VC inside the VP. The VPI is the same for all virtual connections that are bundled (logically) into one VP. Note that a virtual connection is defined by a pair of numbers: the VPI and the VCI.

The lengths of the VPIs for UNIs and NNIs are different. In a UNI, the VPI is 8 bits, whereas in an NNI, the VPI is 12 bits. The length of the VCI is the same in both interfaces (16 bits). We therefore can say that a virtual connection is identified by 24 bits in a UNI and by 28 bits in an NNI.

The whole idea behind dividing a virtual circuit identifier into two parts is to allow hierarchical routing. Most of the switches in a typical ATM network are routed using VPIs. The switches at the boundaries of the network, those that interact directly with the endpoint devices, use both VPIs and VCIs.

• *Cells*

The basic data unit in an ATM network is called a cell. A cell is only 53 bytes long with 5 bytes allocated to the header and 48 bytes carrying the payload (user data may be less than 48 bytes). Most of the header is occupied by the VPI and VCI that define the virtual connection through which a cell should travel from an endpoint to a switch or from a switch to another switch.

• *Connection Establishment and Release*

Like Frame Relay, ATM uses two types of connections: PVC and SVC.

PVC: A permanent virtual-circuit connection is established between two endpoints by the network provider. The VPIs and VCIs are defined for the permanent connections, and the values are entered for the tables of each switch.

SVC: In a switched virtual-circuit connection, each time an endpoint wants to make a connection with another endpoint, a new virtual circuit must be established. ATM cannot do the job by itself, but needs the network layer addresses and the services of another protocol (such as IP). The signaling mechanism of this other protocol makes a connection request by using the network layer addresses of the two endpoints. The actual mechanism depends on the network layer protocol.

2.5.4 Switching

ATM uses switches to route a cell from a source endpoint to the destination endpoint. A switch routes the cell using both VPIs and VCIs. The routing requires the whole identifier.

2.5.5 ATM Layers

The ATM standard defines three layers. They are, from top to bottom, the application adaptation layer, the ATM layer, and the physical layer. The endpoints use all three layers while the switches use only the two bottom layers.

• *Physical Layer*

Like Ethernet and wireless LANs, ATM cells can be carried by any physical layer carrier.

SONET: The original design of ATM was based on SONET as the physical layer carrier. SONET is preferred for two reasons. First, the high data rate of SONET's carrier reflects the design and philosophy of ATM. Second, in using SONET, boundaries of cells can be clearly defined. SONET specifies the use of pointers to define the beginning of a payload. If the beginning of the first ATM cell is defined, the rest of the cells in the same payload can easily be identified because there are no gaps between cells. Just count 53 bytes ahead to find the next cell.

• *ATM Layer*

The ATM layer provides routing, traffic management, switching, and multiplexing services. It processes outgoing traffic by accepting 48-byte segments from the AAL sublayers and transforming them into 53-byte cells by the addition of a 5-byte header.

Header Format ATM uses two formats for this header, one for user-to-network interface (UNI) cells and another for network-to-network interface (NNI) cells. In UNI cell, the header consists of 8 important fields: Generic flow control (GFC), virtual path identifier (VPI), virtual circuit identifier (VCI), payload type (PT), cell loss priority (CLP), and header error control (HEC). On the other hand, the NNI consists of 6 important fields that are similar to the UNI. These fields are VPI, VCI, PT, CLP, and HEC. With these interfaces, the payload data is attached after these fields to transmit over the communication channel.

• Application Adaptation Layer

The application adaptation layer (AAL) was designed to enable two ATM concepts. First, ATM must accept any types of payload, both data frames and streams of bits. A data frame can come from an upper-layer protocol that creates a clearly defined frame to be sent to a carrier network, such as ATM. A good example is the Internet. ATM must also carry multimedia payload. It can accept continuous bit streams and break them into chunks to be encapsulated into a cell at the ATM layer. AAL uses two sublayers to accomplish these tasks.

Whether the data are a data frame or a stream of bits, the payload must be segmented into 48-byte segments to be carried by a cell. At the destination, these segments need to be reassembled to recreate the original payload. The AAL defines a sublayer, called a **segmentation and reassembly (SAR)** sublayer, to do so. Segmentation is at the source; reassembly, at the destination.

Before data are segmented by SAR, they must be prepared to guarantee the integrity of the data. This is done by a sublayer called the **convergence sublayer (CS).**

ATM defines four versions of the AAL: **AAL1, AAL2, AAL3/4, and AAL5.** The common versions today are AAL1 and AAL5. The first is used in streaming audio and video communication; the second, in data communications. Therefore, only these 2 versions of AAL were introduced in this Thesis.

AAL1

AAL1 supports applications that transfer information at constant bit rates, such as video and voice. It allows ATM to connect existing digital telephone networks, such as voice channels and T lines.

The **CS sublayer** divides the bit stream into 47-byte segments and passes them to the SAR sublayer below. However, the CS sublayer does not add a header.

The **SAR sublayer** adds 1 byte of header and passes the 48-byte segment to the ATM layer. The header has two fields: Sequence number (SN), and Sequence number protection (SNP).

- *Sequence number (SN).* This 4-bit field defines a sequence number to order the bits. The first bit is sometimes used for timing, which leaves 3 bits for sequencing (modulo 8).

- *Sequence number protection (SNP).* The second 4-bit field protects the first field. The first 3 bits automatically correct the SN field. The last bit is a parity bit that detects error over all 8 bits.

AAL5

AAL3/4 provides comprehensive sequencing and error control mechanisms that are not necessary for every application. For these applications, the designers of ATM have provided a fifth AAL sublayer, called **the simple and efficient adaptation layer (SEAL).** AAL5 assumes that all cells belonging to a single message travel sequentially and that control functions are included in the upper layers of the sending application.

2.6 Quality of Service (QoS)

Quality of service [49] is an internetworking issue that has been discussed more than defined. We can informally define quality of service as something a flow seeks to attain.

Flow Characteristics

Traditionally, four types of characteristics are attributed to a flow: reliability, delay, jitter, and bandwidth.

• ***Reliability***

Reliability is a characteristic that a flow needs; lack of reliability means losing a packet or acknowledgment, which entails retransmission. However, the sensitivity of application programs to reliability is not the same. For example, it is more important that electronic mail, file transfer, and Internet access have reliable transmissions than telephony or audio conferencing.

• ***Delay***

Source-to-destination delay is another flow characteristic. Again applications can tolerate delay in different degrees. In this case, telephony, audio conferencing, video conferencing, and remote log-in need minimum delay, while delay in file transfer or e-mail is less important.

• ***Jitter***

Jitter is defined as the variation in the packet delay. High jitter means the difference between delays is large; low jitter means the variation is small. In multimedia communication, if the jitter is high, some action is needed in order to use the received data.

• *Bandwidth*

Different applications need different bandwidths. In video conferencing millions of bits need to be sent per second to refresh a color screen, while the total number of bits in an e-mail may not reach even a million.

2.7 Literature review

Various researches in network management policy have shown that setting a good architecture with good management policy supports efficiency of data transfer over the network design architecture. Network management problems generally concern for some values, such as data transfer rates, delay, and jitter values. These values depend on various objects and applications. Therefore, the study to implement a generic framework policy for diverse management applications is proposed by [1]. This framework includes domain space which consists of objects of interest in the application, rule space which consists of if-then rules, action space whose actions are dependent on the application, and policy driver whose functions are to monitor the attributes of objects in the domain, compare the values of attributes with rules, resolve conflicts, and then execute the selected rule.

Since network technologies have been improved continually, there are various kinds of network architecture to be chosen. Each architecture has its own benefit. Thus, promoting of the interoperability of several networks can improve a performance of each network type, as proposed in heterogeneous network research. For instance, the result from [2] has shown that the hybrid network has higher efficiency than the network implemented in either cable or wireless located at the rural area. From the view point of cost, [3] proposed a cost effective in-building signal distribution network. IEEE 802.11g WLAN system is used to illustrate the range extension a multimode Radio-over-Fiber network can provide. The Radio-over-Fiber (ROF) network allows simplified remote distribution units while the base stations are kept in a central office for ease of maintenance and upgrades. The performance of this ROF network surpasses the performance of current alternatives in terms of performance, cost and weight. Furthermore, [4] has realized that interoperability at various levels is vital for the success of the heterogeneous network. Consequently, it has presented Possible IN-based network architecture for global broadband and mobile networks. The Intelligent Network (IN) concept has proved useful in several network design issues particularly in the areas of vendor-independent service deployment and in location management in mobile networks. In addition, improvement on wireless network over cabling system is an efficient way to support portability, scalability, comfort, and implementation in addition to cost-effectiveness and reduced implementation time.

As the fact that most networks are heterogeneous, the management policy must be determined differently from a single or homogeneous network in order to obtain its efficiency and high performance. Thus, an integrated network management architecture for managing heterogeneous networks using an application program interface and lower layer manager has been proposed by [5] in the year 2000. This proposed architecture can accept the existing networks of management systems. Also, an integrated network management system was designed and implemented that could manage both LANs and WANs using SNMP and a proprietary network management protocol according to the software development procedure. The implemented integrated network management system can support a unified user interface on a hardware platform and maintain both LANs and WANs. In 2004, [6] presented related system integration requirements and provide a new framework to support the integration of 4G networks and services. This framework uses a policy based networking concept in order to provide the unified control in the oncoming 4G networks and services.

Likewise, an automated policy-based management in heterogeneous access network environment is a challenge today. Hence, in 2007, [7] focuses on a toolkit for intelligent management of resource allocation in heterogeneous network (UMTS, WIMAX, WLAN DVB-T, DVB-H) infrastructures based on policies of different actors (network operator, service providers and users), so that the policy-based management of resources for QoS-aware applications (Video-on-Demand, Mobile TV), which depends on network capabilities, context learning and preferences of the policy actors, is proposed in this paper. Furthermore, [8] presents a paradigm to approach the issue of autonomous policy-based management of wired/wireless differentiated communication systems. A hierarchical policy model is used to capture users and administrators' higher level goals into network level objectives. Given sets of network objectives and constraints, policies are assembled at runtime. This approach gives more flexibility to users and applications to dynamically change their quality-of-service (QoS) requirements while maintaining a smooth delivery of QoS through network monitors feedback. Also, to support QoS guarantee and resource usage in heterogeneous access network environments more efficiently, [9] proposed a policy management architecture, which allows interaction and adaptation of QoS policies of different actors, such as network operator, service provider and user based on common a policy repository.

Since situation of traffic flow in the communication channel is relied on the load balancing mechanism arranged by routing devices, a load balancing scheme for centralized wireless networks has been proposed by [10] in the year 2005. This mechanism uses the capability that users in the overlapping area between cells can efficiently and dynamically be reconnected to one of the accessible base stations by a central control station. However, balancing mechanism may affect to processes of any service-oriented systems. Therefore, the QoS of service-oriented monitoring framework is an important issue to be considered to protect any undesired situations. Thus, [11] proposed a service oriented monitoring framework inside wired and wireless access/core networks to control and guarantee the QoS between providers and users.

According that the satisfaction of users is based on the performance of the data transfer rate over the integrated networks, [12] proposes a generic framework for the performance of this architecture. There are four basic steps identified in this proposed framework. First, measurable performance parameters must be identified and their acceptable ranges and recommended values established. Second, the measurement points for these parameters must be established. So, they may be evaluated consistently from time to time and from network to network. Third, measurement tools must be identified and when not available, specifications for new tools should be developed. Finally, the limitations of the tools must be determined and the measurement variances identified.

Since the use of web applications is rapidly grown, the management and scalability of networks will become an important issue to be considered. Thus, in 1999, [13] had proposed a hierarchical, Web and platform-based network management architecture for resolving problems of scalability, management efficiency, and manager autonomy in large, multiple domain networks. This architecture consists of multiple domain managers and a manager of managers, each responsible for a different management domain, and each can run independently or cooperatively. Moreover, a network management layer that support generic and scalable network for managing network devices from different vendors and technologies was proposed by [14]. This technique focuses on SNMP over the ADSL/ATM networks with different network components, such as resource adapters, element manager layer connection performers, network management layer connection performers and route servers. Moreover, [15] had proposed the implementation of an intelligent resource management (IRM) scheme for using in emerging broadband cable networks. It has shown that the IRM scheme performs better than conventional scheduling schemes. Specifically, the scheme can manage and control bandwidth-intensive applications, and provide fair bandwidth allocation. The broader impacts of the IRM scheme are the ability to mitigate serious security problems, and the ability to deliver quadruple play services while meeting required performance metrics.

Considering services over a hybrid network, network links between multi-hops connectivity of ad hoc network and IEEE 802.11 wireless LAN. Responsibility and efficiency of the routing protocol must be clearly defined and implemented in both directions of uplink and downlink traffics. Thus, [16] proposed a routing protocol named Flexible Mobile Access Routing Protocol (FMARP) to efficiently perform uplink routing and downlink routing. In FMARP, uplink routing is simply forwarding packets to the parent node in the routing tree, and downlink routing is the reverse path of its latest uplink packet. In the year of 2007, [17] designs an advanced routing protocol for wired and wireless integrated networks by modifying the existing ad hoc routing protocol to enable access to wired networks, such as the Internet. In this architecture, the wired and wireless integrated networks transmit the information collected from the wireless sensor networks to wired networks via WSN Gateway.

Since this research emphasized on improvement a network performance by installing of wireless technology over the originally wired network. Thus, the advantage, disadvantage, as well as common features, such as throughput, of this wireless technology should be well studied. In 2005, [18] presented the results of experiments to study throughput behavior and determine the maximum attainable throughput in an 802.11g wireless LAN under UDP traffic. The studies show that in almost all cases the observed throughput is well below 50% of the 802.11g maximum data rate of 54 Mbps even under ideal and controlled conditions. Although network card implementation and use of RTS/CTS have a significant impact on throughput, access point distance has little effect. In the year of 2007, [19] has revealed the benefit of IEEE 802.11g that Wireless Mesh Networks (WMNs) provide a reliable and cost effective solution to extending coverage in a rural fixed network, and simulation results has shown that the star mesh network is a feasible, low cost, robust solution. Additionally, it is very important to study the behavior of the wireless networks due to the variety of applications that make use of this technology. These applications frequently require a minimum QoS in order to work properly and guarantee a good service to the user, as mentioned in [20] in 2008. According to its results, the delay and the packet loss are affected as the SNR ratio decreases, while jitter has an exponential growth when the signal decreases from 19 to 11 dB, and the optimal range for most of the real time applications (as VoIP) goes from 34 – 90 dB, at this range it is found a good QoS in the network performance.

To acquire the high performance of this wireless technology, research on performance analysis of the 802.11g should be determined as well. Therefore, the objective of [21] is to study the performance of 802.11b and 802.11g standards in real-time while implementing an actual file transfer. This study revealed that, for both of standards, 802.11b and 802.11g, protocol congestion is one of the major factors leading to delay in the file transfer scenario. Moreover, the study also highlighted that a small amount of latency is introduced in case of 802.11g when the client node is placed far away but within the coverage area of the access point. Particularly for Indoor usage, [22] investigated the throughput performance of an IEEE 802.11g wireless local area network (WLAN) under different received signal strength (RSS) values using indoor propagation measurements. Results obtained show that the link throughput of an IEEE 802.11g is not always increasing with RSS in an obstructed office building, and the number of active stations has a significant impact on mean packet delay and throughput of IEEE 802.11g. It is also found that the performance of an IEEE 802.11g network with a single access point significantly degrades for $N > 15$ wireless stations in a typical office environment.

For enhancing the reliable range of IEEE 802.11g, [23] have applied diversity technologies to the IEEE 802.11g to use the IEEE802.11g in moving channel environments. After analyzing the measurement data, it is shown that the reliable communication range is 63m when transmitting power is 10dBm, while the range increases to 163m when the diversity technique is used. Also the communication range increases from 122m to 306m by using diversity technologies when the transmitting power is 20dBm.

Since wireless technology offers many advantages, and Healthcare requires a new way to manage current challenges and thereby provide cost effective quality care to all users. Thus, the combination of wireless in healthcare appears to be a real solution, as mentioned in [24]. In this paper, it emphasized on the importance of thinking of wireless as a strategic necessity in healthcare delivery for this 21st Century and it also urges for more research in this area as well as for healthcare institutions globally to move forward in this direction. This research has shown that mobile/wireless solutions for healthcare can achieve four critical goals of Improvement of Patient Care, Reducing Transaction Costs, Increasing Healthcare Quality, and Enhancing Teaching and Research. In addition, [25] describes an elegant and intuitive wireless healthcare application for prescription writing and laboratory test review which leverages the Internet and significantly enhances productivity of physicians, clinical laboratories, pharmacies, while at the same time saving patients time, improving accuracy in healthcare and provides an insight into future trends in healthcare applications.

As mentioned, the well interoperability of heterogeneous network can enhance performance of each network type. Therefore, in the year of 2004, [26] presented a proven reference architecture for a secure enterprise mobile healthcare solution for hospital physicians and nurses. The solution furnishes access to several medical information systems whilst supporting a capability to roam within and outside the hospital environment. This was obtained by seamless roaming between the 802.11 and GSM/CDMA mobile networks. Additionally, in 2007, [27] has mentioned that the integrating of the wireless network and cellular network had helped to expand the coverage range and enhance the mobility of the system. Mobile healthcare application had eased the mobile users to merge cellular phone with the wireless enabled devices for entitling in flexi and portable healthcare solution at any places. This helps to empower the communication between doctors and patients by keeping doctors the patients' latest health condition. Besides, the health parameters self-monitoring not only reduces the overhead of the network traffic but also the overall hospitalization period and cost.

Likewise, it also plays an important role on patient monitoring system, which becomes a requirement for offering a better healthcare to an increasing number of patients in nursing homes and hospitals. In 2008, [28] presented a wearable ECG monitoring system for ubiquitous healthcare that offers a powerful new way to keep track of a patient's heart status and predict impending events. The post-layout simulation results show that the smart electronic electrode with ultra low power consumption is quite feasible for a hand-held PHA which uses a battery as energy source.

As well, a novel In-community healthcare monitoring system is introduced in [29]. The topology structure of the system is three-tier: BSN tier, Community server tier, and Medical service tier. The advantages of this architecture are as follow: there is no gap between BSNs and WSN for they use the same 802.15.4/ZigBee protocol, the patients need not pay high daily wireless communication fee, and the reconstruction of such networks can be scalable and easily configurable according to the WSN's features. In addition, based on an existing monitoring network tool, namely MRTG, [30] has proposed an infrastructure for recording environmental and biological variables, in order to achieve a remote, reliable, secure and efficient real-time access to this data which may be displayed on a PDA.

Improvement on query process can support the efficiency of healthcare monitoring system. Consequently, in the year of 2007, [31] describes a query supported healthcare system using USN platform for health monitoring. This system is capable of obtaining physiological data from sensor attached to patient's body and transfers it wirelessly to a remote base-station in an ad-hoc network, following IEEE802.15.4 standard (Zigbee) for wireless communication. Query supported healthcare system has the potential to provide a better to patients, doctors and caregivers through continuous health monitoring because it can reduce energy consumption which enables the nodes to transfer data only when desired and sleep for the rest of the time. In 2008, for Indoor environmental and Healthcare monitoring system, [32] introduced the implementation of the query processor of broadcasting type and flooding type for reliability query transmits to destination node. The experimental results have shown that the flooding type query processor has better performance than broadcasting type query for the query losses and reliability from terminal PC to destination node.

During the monitoring period, vital signs of patients could fluctuate significantly and/or match certain undesirable patterns and, therefore, "alerts" or emergency messages must be delivered to healthcare professionals. Thus, in 2006, [33] proposed that ad hoc networks can be formed among patients' devices for improved transmission of emergency messages. It also proposed several design enhancements to improve the quality and coverage of patient monitoring. The performance results for the proposed ad hoc network based architecture show that reliable message delivery and low monitoring delays can be achieved using multicast or broadcast-based routing schemes. Since the congestion situation might be occurred in the communication channel, it would be a serious problem in case of emergency message. Hence, in 2008, a novel balanced clustering is formulated to balance the distribution of agents within the base station network, as presented in [34]. The balanced clustering considers the minimum load variation of the network by deploying agents from loaded base station to other least loaded base station. The algorithm considers the QoS by employing the nearest neighbor deployments. The mobile agent distribution is based on a threshold value to optimize the load distribution. Simulation evaluation shows that the proposed balanced clustering is efficient in distribution of loads and considers the QoS from clients by minimizing the communication hops in deploying the mobile agents.

Due to the fact that policy is flexible and can be adapted by the perspective of service providers, users, or even customers, it is utilized in healthcare system to enhance performance in several aspects, such as enhancing QoS, authorization, and reliable transmission. Thus, the system can achieve better care for their patients, and also reduce the risk of patients' life in emergency cases. For instance, [35] defines different group types and proposes a framework, which allows for the dynamic management of such groups using policies, in the year of 2008. Since the authors believe that successful medical emergency preventative measures or actual emergency resolution is not entirely down to one individual, but more the result of the establishment and behavior of a group of individuals and services. This is highly evident in the healthcare domain: the introduction of pervasive healthcare systems allows for the interconnection of various stake holders, such as patients, doctors, medical monitoring services, and the patients' families. Therefore, communication within a group can be extremely useful to manage and resolve emergency situations, such as helping a patient affected by a life-threatening hypoglycemic condition. Additionally, [36] designs a policy system that implements policy-driven management on the sensor level. Biosensor adaptability is realized through support of dynamic loading, enabling and disabling of policies without shutting down nodes. In addition, fine-grained access control becomes possible through authorization policies on biosensors. Experimental results demonstrate that the policy system is viable and can accelerate application development of biosensor networks for healthcare.

There are some types of diseases in which one cannot be able to move their bodies, cannot speak, and cannot share their feeling to rest of the world. So, the aim of [37] is to solve the problem of persons who are suffering from such type of diseases. In this system, the eye blinking is used as a parameter to communicate with rest of the world.

Moreover, although the healthcare system is improved in several aspects, such as interoperability, hardware, interfaces and routing protocols, in order to acquire better care for patients with cost-effectiveness, security in this kind of services is also necessary for protecting patients' privacy. In 2005, [38] mentioned that m-Health is a new and evolving research discipline that is defined as emerging merging mobile communications and network technologies for healthcare. It is also important that in order to achieve wireless global connectivity from the healthcare perspective a new standardization procedures and protocols defining the specific security and privacy sensitive services, such as mobile healthcare systems need also to be researched further and investigated to provide a visible standards for 3G based and beyond 3G based wireless healthcare systems and services. Additionally, in the year of 2006, [39] had presented a mobile healthcare system prototype based on surrogate host system. The surrogate host provided seamless interface between mobile devices and a Grid portal. For security the proxy-based GSI is extended to provide authentication of wireless devices. The experimental results showed that the developed system could be utilized to provide patients with real-time heart disease diagnosis based on Grid computing in a secure and convenient manner.

From above, healthcare system in several perspectives is improved for quality of service. This improvement is not only important for healthcare system which serves low cost of healthcare services at home, it also necessary for healthcare organization which provides medical services to patient directly. Consequently, [40] has presented an application of Cooperative management Methodology for Enterprise Networks (CoMEN) methodology to analyze a cooperative work scenario in healthcare. Since the authors of this paper believed that the implementation of an automated system is supposed to provide more accurate and timely information on patient requirements and streamline the work practices by reducing inefficient repetitive manual tasks. In the analysis, some unsatisfactory interactions among users could be identified. Although a substantial amount of resources are spent on latest computer based medical systems, the desired level of QoS is not achieved due to the lack of skill levels of people managing these systems. Hence, this study suggests the necessity for effective communication techniques among users and skills upgrading of system support personnel to improve the service levels and productivity.

Since there are different levels of user requirement in network utilization, the quality of service for each level is different as well. Consequently, prioritization is required for managing appropriate services to user. In addition, many researches proved that better performance as well as quality of service is obtained due to applying prioritization to a system. Besides, prioritization level is flexible and can be changeable, when the objective is changed in the future. Therefore, this idea is utilized in various kinds of networks, such as cellular, wireless, and wired networks.

For the cellular network, [41] proposed a new media access control protocol, named Dynamic Reservation Protocol, for multi-priority multi-rate data services on GSM networks. In this protocol, data terminals can obtain their uplink channels through contention-free reservation. Therefore, this protocol can achieve very high channel utilization efficiency and can significantly improve the service performance under the heavy traffic load. The reservation scheme can adapt to traffic variations, by dynamically changing the transmission cycle length. Simulation results show that this protocol offers significantly better delay/throughput performance when compared to other protocols proposed in the literature.

In 1998, [42] presented a multi-priority CDMA system to enhance capacity while maintaining Quality of Service (QoS). The capacity of multi-priority CDMA system with integrated services was evaluated, the results illustrate that multi-priority method gives system excessive capacity without deteriorating QoS of high priority user. In the year of 2006, based on delay reservation control, a multi-priority delay reservation CAC scheme is proposed in [43]. Numerical results show either the service of high priority traffic or the service of low priority traffic is guaranteed in the CAC scheme with multi-priority delay reservation, and the utilization of the network is also promoted especially when the network load is heavy.

For wireless network, in 2004, [44] presented MPARC (Multi-Priority Admission and Rate Control), a joint admission control and rate policing protocol for multi-priority ad hoc network. Through simulation, MPARC achieves accurate admission control of real time traffic and rate policing of best effort traffic, which ensures that throughput guarantees for real time flows are maintained and at the same time the network utilization is efficient.

In 2005, multi-priority application framework has been proposed in [45]. It provides service differentiation mechanism. An appropriate treatment is given to each traffic type depending upon its priority value. High priority traffic is allowed to send its packets more frequently than that of the low priority traffic. The simulation result showed that the performance of the voice and video traffic improves significantly in terms of throughput, delay and packet loss ratio under all mobility conditions. The best effort degrades due to its lowest priority and least channel share. Additionally, in 2006, [46] describes a research project using Colored Petri Net (CPN) to simulate and validate alarm integrity in a small multimodality wireless patient monitoring system. A 20-monitor wireless patient monitoring network is created in two versions: one with non-prioritized 802.x CSM protocols and the second with simulated Quality of Service (QoS) capabilities similar to 802.11e (i.e., the second network allows message priority management.) In the standard 802.x network, dangerous heart arrhythmia and pulse oximetry alarms could not be reliably and rapidly communicated, but the second network's QoS priority management reduced that risk significantly.

For wired network, [47] investigated the performance of switched-Ethernet LANs when transporting real-time video streams. Its study covers several switched-LAN topologies that employ switches with different capabilities. Such capabilities include the use of shared versus dedicated ports and single versus multi-priority access buffers in the switch ports. The results show the impact of LAN switch parameters on the delay and loss performance of real-time video streams, and some advantage can be observed when using dual-priority switches for low-bit rate (and less bursty) H.263+ streams.

CHAPTER III

NETWORK ARCHITECTURES AND PROPOSED POLICIES

This chapter describes the network architectures and the proposed policies of this Thesis. In this experiment, there are 2 main types of network architectures, which are the simulated architectures and the real architectures. Therefore, the simulated architectures are explained in Section 3.1, and real architectures are explained in Section 3.2.

3.1 Simulated Architecture

In these simulated architectures, a Medicare system is established in four types: Wired Network, Wired Network with policy, Wired and Wi-Fi Networks, Wired and Wi-Fi Networks with policies. Performance of these architectures will be compared each other in order to find out the best solution for designing the network architecture as well as the policy, before moving to a real architecture.

To simplify the Medicare system, transmission of data between servers and clients was performed by excluding the security issue. Moreover, the applications from the wired networks of all simulated architectures are served only for the main tasks in the hospital, while the applications from the wireless networks are supported for minor purpose, such as Internet services. For that reason, consideration of the appropriate wired policies is differ from the wireless policies. Thus, each policy will independently manage transmitted applications in the Medicare system.

3.1.1 Wired Network

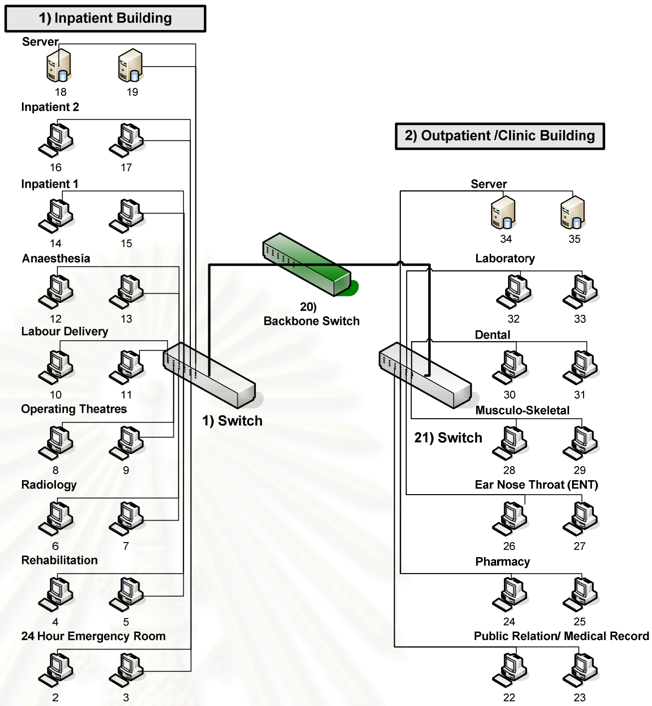

Figure 3.1: Wired network of the Medicare system

• *Network Architecture*

In general, a hospital consists of 2 fundamental buildings: Inpatient Building, and Outpatient Building. Additionally, it usually installs a wired network as its core network. Therefore, a wired network of the Medicare system is established for these 2 buildings.

Inpatient Building consists of 9 departments, which are 24 Hour Emergency Room, Rehabilitation Department, Radiology Department, Operating Theatres Department, Labour Delivery Department, Anaesthesia Department, Inpatient 1 Department, Inpatient 2 Department, and Server Department.

Outpatient building consists of 7 departments, which are Medical Record Department, Pharmacy Department, Ear Nose Throat (ENT) Clinic, Musculo-Skeletal Clinic, Dental Clinic, Laboratory Department, and Server Department.

Moreover, all departments connect to the servers for receiving information used in each building. For instance, all clients in each department will request to servers, which are node 19 for the Inpatient Building, and node 34 for the Outpatient Building, from the server department for medical information used for diagnosis.

• *Simulation Model Description*

This architecture has a core network as Gigabit Ethernet (IEEE 802.3). It is a switched network in the full-duplex mode.

For simplifying the system, the general configuration is used for this simulation. As recommended by Qualnet, IP Queue type is First In First Out (FIFO) which a number of priorities are eight, and scheduler type of this queue is strict priority. Furthermore, the service transfer type is the Constant Bit Rate (CBR), and the MAC frame size is 1024 bytes.

After specified the minimum simulation time by detecting the relationship between channel utilization and the simulation time, the result has shown that the first point that the channel utilization begins to change slightly is 40 minutes. Thus, this simulation was performed at 40 minutes. Hence, the remaining of simulated architecture will be performed using this time as well.

Based on the maximum of lines, offered load can divided into 5 data transmission rates, which each interval is 250 Mbps. in order to evaluate network performance at various conditions. Therefore, the wired network is simulated by varying offered loads of the entire system as 250, 500, 750, 1000, and 1250 Mbps. In addition, these loads are also offered to other wired networks of the remaining simulated architectures.

3.1.2 Wired Network with policy

• *Network Architecture*

This architecture is similar to the previous one, except that it is applied a network management policy in this network system. A detail of this wired policy is explained as follow.

Wired Policy: it was set up by considering an important of each department. Thus, the highest priority is set for the departments which are significantly in vital, in addition that some tasks were required for the short delay time of an incoming message. Additionally, the middle priority is set for departments that their tasks involve in various kinds of applications or their information are sometimes need to be transmitted to doctors as requested. Furthermore, setting up the lowest priority is for the department that used only data in their main tasks, or a long delay time is acceptable in these departments. As a result, the policy for the wired network in the Inpatient building and Outpatient building is shown as follow:

Table 3.1: Wired policy

Priority	Inpatient Building	Outpatient Building
Highest	Emergency room, Operating Theatres, Labour Delivery	Ear Nose Throat (ENT) clinic, Musculo-Skeletal Clinic, Dental Clinic
Middle	Rehabilitation, Anaesthesia	Laboratory
Lowest	Radiology, Inpatient 1, Inpatient 2	Medical record, Pharmacy

• *Simulation Model Description*

It's the same as in the wired network model, except that it is also applied the precedence to application which is transmitted from each department.

3.1.3 Wired and Wi-Fi Networks

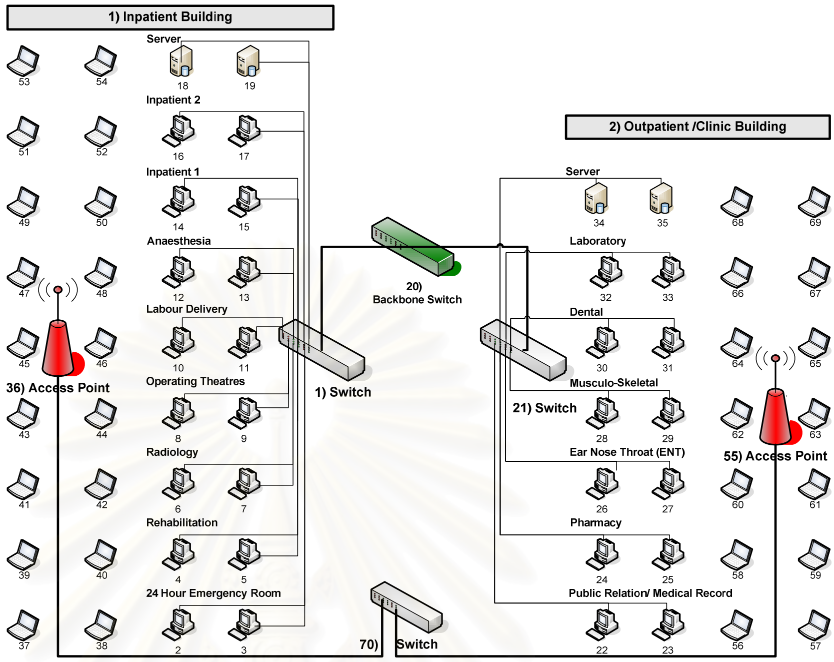

Figure 3.2: Wired and Wi-Fi networks of the Medicare system

• *Network Architecture*

In this architecture, it installed the Gigabit Ethernet as in the wired network model and also installed a wireless network (IEEE 802.11g) as an alternative one. In addition, this architecture can be defined as **Overlap-network** which has the wired as core network overlapped with the wireless. In doing so, it does not only help relieve congestion situation of a core network in high traffic load, but it also support portability, scalability, and maintenance.

Thus, a detail of the wired and Wi-Fi networks model is described here.

Wired: a wired network in this architecture is unchanged, as mentioned in the wired network model. Also, node 19 and node 34 act as servers in the Inpatient Building, and the Outpatient Building, respectively.

Wi-Fi: wireless devices can communicate to each other via Access Point (node 36 and node 55) in each building, and the node 18 and node 35 will act as Wi-Fi servers for transmitting their information to all wireless devices in the Inpatient building, and the Outpatient Building, respectively.

Wi-Fi devices of patients are represented in odd nodes of the Inpatient Building, and in even nodes of the Outpatient Building, while the rest ones are represented the Wi-Fi devices of doctors.

• *Simulation Model Description*

Since it is the Overlapping between cabling and wireless networks, the simulation can be separated into 2 networks:

Wired: It is similar to the wired network model, which is a Gigabit Ethernet (IEEE 802.3), and is a switched network in the full-duplex mode.

Wi-Fi: the wireless technology used in this architecture is IEEE 802.11g, with the data rate is 54 Mbps. Although the data rate of this technology can be reach up to 54 Mbps. in theory, its typical throughput is about 20 Mbps. For that reason, in this experiment, some applications, which all have the data rate about 20 Mbps, were split from the wired and transmitted via Wi-Fi instead. To illustrate this point, 20 Mbps. of data rate is split from the entire system which has the offered loads as 250, 500, 750, 1000, and 1250 Mbps. So, the wired network will transmit at 230, 480, 730, 980, and 1230 Mbps, respectively.

Generally, there are 2 main types of applications transmitted via Wi-Fi for providing alternative services in the hospital. Firstly, applications are provided for patient information, and secondly, applications are used to serve Internet services to doctors. In addition, due to the fact that, recently, hospital tends to provide Internet services for their patients while waiting for diagnosis, Internet services for patient are also included in this experiment as well.

In order to measure the network performance of each flow fairly, Wi-Fi applications consist of 2 categories: one for doctors with 10 Mbps, and the other for patients with 10 Mbps. Moreover, applications for doctors are split into 2 subcategories: patients' information for doctors and Internet services for doctors, which each has 5 Mbps of data transmission rate. Consequently, all 20 Mbps. of the data rate in the wireless network can be divided into 3 application types: patient information for doctors with 5 Mbps data rate, Internet services for doctors with 5 Mbps data rate, and the Internet services for patients with 10 Mbps data rate. Likewise, the service transfer type is the Constant Bit Rate (CBR), and the MAC frame size is 1024 bytes.

3.1.4 Wired and Wi-Fi Networks with policies

• ***Network Architecture***

This architecture is similar to the wired and Wi-Fi networks model, except that it is applied the network management policies in both of wired and wireless networks. Since there are two networks cooperated with each other, the policies for this architecture are determined carefully in order to achieve the high performance in each network type as well as in the entire system. Therefore, setting up policies for wired and wireless networks is determined differently as follow.

Wired policy: it was unchanged as in the wired network with policy model, which is determines a precedence of each application according to ***an important of each department.***

Wireless Policy: determining for setting up the wireless policy is differed from the wired network; it is because transmitted applications from the wired are the only task served for the needs of the hospital. In contrast, applications from the wireless network can be transmitted from doctors who request information for helping their diagnosis, or transmitted from the patients who would like to surf the Internet while they are waiting for doctors. Moreover, if this wireless policy was set up by considering only the important of each department according to the wired, the applications for significant information from the lower priority departments can be blocked by the Internet applications from the higher priority departments.

Therefore, the priority for Wi-Fi applications is set up by determining the ***objectives and user types.*** Accordingly, there are 3 types of applications, which are applications from patient information for doctors, Internet services for doctors, and Internet services for patients. For authentication, if applications are for doctors, or staffs who work in the hospital, the system requests for passwords when connecting to Wi-Fi services. On the other hand, if users are patients who would like to access the Internet using Wi-Fi services, they can connect without requesting any passwords. Then, the policy for these Wi-Fi applications is shown in Table 3.2.

Table 3.2: Wireless Policy

Priority	Type of Wi-Fi application
Highest	Patient information for doctors, or staffs within the hospitals
Middle	Internet services for doctors, or staffs within the hospitals
Lowest	Internet services for patients

• ***Simulation Model Description***

The wired and Wi-Fi networks with policies model is mainly simulated as in the wired and Wi-Fi networks model, except that it is applied policies in both of wired and Wi-Fi of this architecture.

In wired, applications are prioritized according to an important of each department, while they are done by objectives and user types in Wi-Fi.

3.2 Real Architecture

After interviewing with a doctor from Chulalongkorn Memorial Hospital, current network architecture of this hospital is collected. Even though this network can work properly at this time, utilization of network is increased continually. So, the hospital plans to upgrade it. Despite the fact that it can enhance a performance of network system, it spent a large amount of money and time. For that reason, Overlap-network with suitable network management policies is proposed in this experiment. This architecture is not only determined from the viewpoint of cost, but also emphasized on reducing delay time in critical information of patients' life within the system. Consequently, the real architectures consist of 3 networks: Current-network, Upgrade-network, and Overlap-network with policies.

Due to differences of wired technologies in these 3 models, the simulations are performed under the same conditions. Consequently, the performance parameters, such as throughput, or delay, are detecting where the ratios of offered loads served for the main task to the maximum load stand at 1:2, 3:4, 1:1, and 5:4. Therefore, the loads, which are offered to the Current-network and the Overlap-network with policies, are 50, 75, 100, and 125 Mbps, based on the maximum load of Fast Ethernet in their access network. Besides, offered loads for the Upgrade-network are 500, 750, 1000 and 1250 Mbps, since the wired technology in this model is Gigabit Ethernet. In doing so, the performance of these 3 network models will be evaluated reasonably.

In this experiment, information is transmitted between server and clients without consideration of authentication and authorization of the information in order to simplify the network system. Consequently, the simulations were performed by excluding the security issue. For all real architectures, applications from the wired networks are represented only the routine work in the Medicare system, while applications from the wireless are represented according to the objectives and user types so that the proper policy for each type of network is determined differently. Thus, wired and the wireless policies will organize the transmitted applications independently.

3.2.1 Current-network

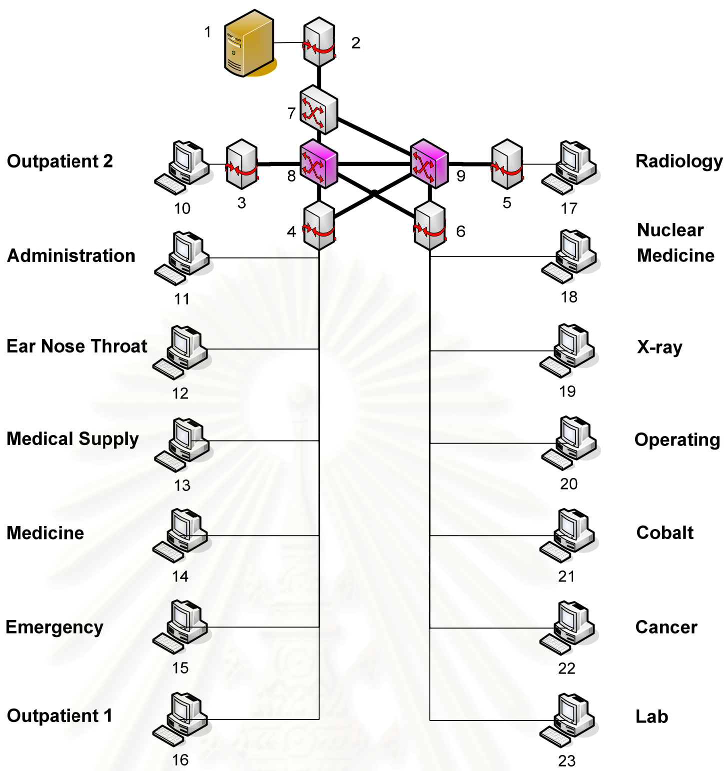

Figure 3.3: Current-network

• *Network Architecture*

According to this architecture, it has 14 buildings, which are Outpatient 2, Administration, Ear Nose Throat, Medical Supply, Medicine, Emergency, Outpatient 1, Radiology, Nuclear Medicine, X-ray, Operating, Cobalt, Cancer, and Lab.

In this system, it has only one server (node 1), which is in the Outpatient 2 building. Moreover, there are 2 types of wired technologies used in this Current-network: the core is Asynchronous Transfer Mode (ATM), while an access network in each building is Fast Ethernet.

Hence, in this experiment, node 10-23 represent a client in each building, and node 8-9 act as ATM Core Switches. Due to a difference in these 2 technologies, gateways (node 2-6) is applied for communicating between clients, which are Fast Ethernet, and the core switches that are ATM Switches.

• *Simulation Model Description*

As mentioned, IP Queue type is First In First Out (FIFO), the number of priorities are eight, and scheduler type of this queue is the strict priority. Furthermore, the service transfer type is the Constant Bit Rate (CBR), the MAC frame size is 1024 bytes, and the simulation time is 40 min. Also, these configurations are used in the simulations of Upgrade-network, and Overlap-network with policies.

Since this architecture has 2 types of wired technologies merging together, the simulation can be separated into 2 parts:

ATM: it is simulated as a core network of this architecture, and its link bandwidth is 155 Mbps.

Fast Ethernet: an access network in each building is Fast Ethernet (IEEE 802.3), which carries traffic at the nominal rate of 100 Mbps, in the full duplex mode.

3.2.2 Upgrade-network

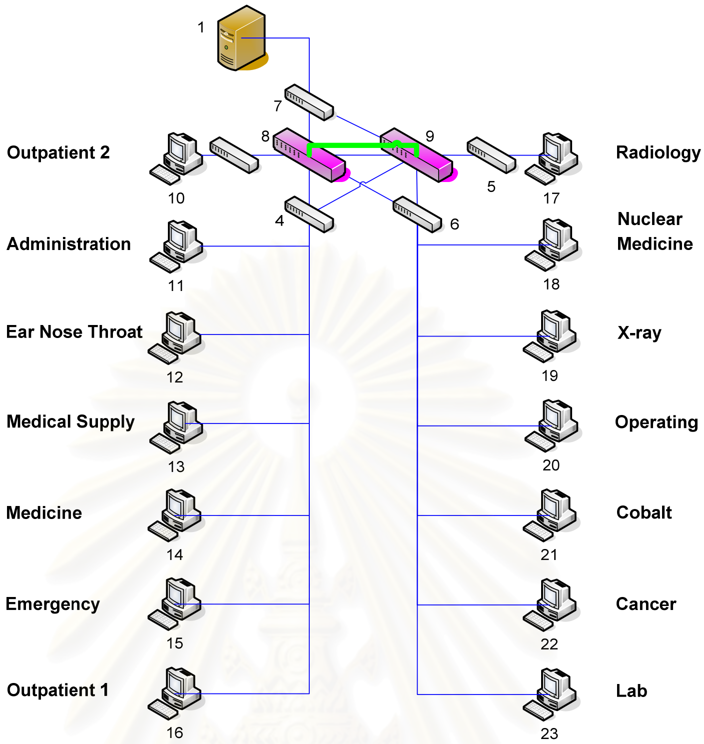

Figure 3.4: Upgrade-network

• *Network Architecture*

All components of this architecture are mainly similar to the Current-network, except that wired technologies, which are ATM in the core network and Fast Ethernet in the accessed network, are changed to the Gigabit Ethernet in order to support the increased requirements of users. Therefore, the Gigabit Ethernet is installed in both of core and accessed network of this Upgrade-network. Moreover, it is also added a second link, which is 10Gigabit Ethernet, between Core Switches to lighten the traffic load connected to a server.

• *Simulation Model Description*

As mentioned, Gigabit Ethernet (IEEE 802.3) in the full duplex mode is simulated as the wired technology of both core and accessed network, and it is also add 10Gigabit Ethernet line as the second link between two core switches.

3.2.3 Overlap-network with policies

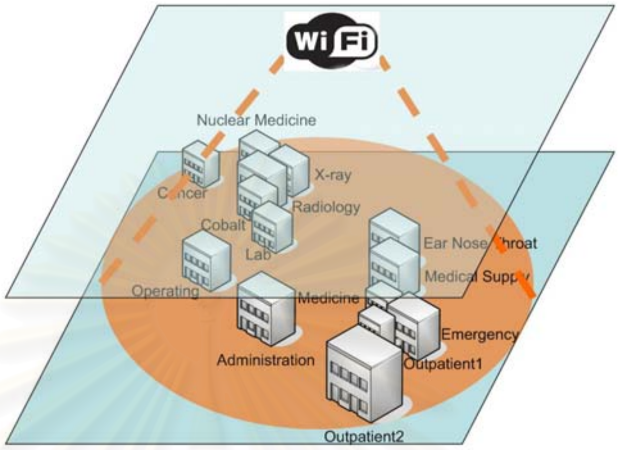

Figure 3.5: 3D view of Overlap-network with policies in Healthcare organization

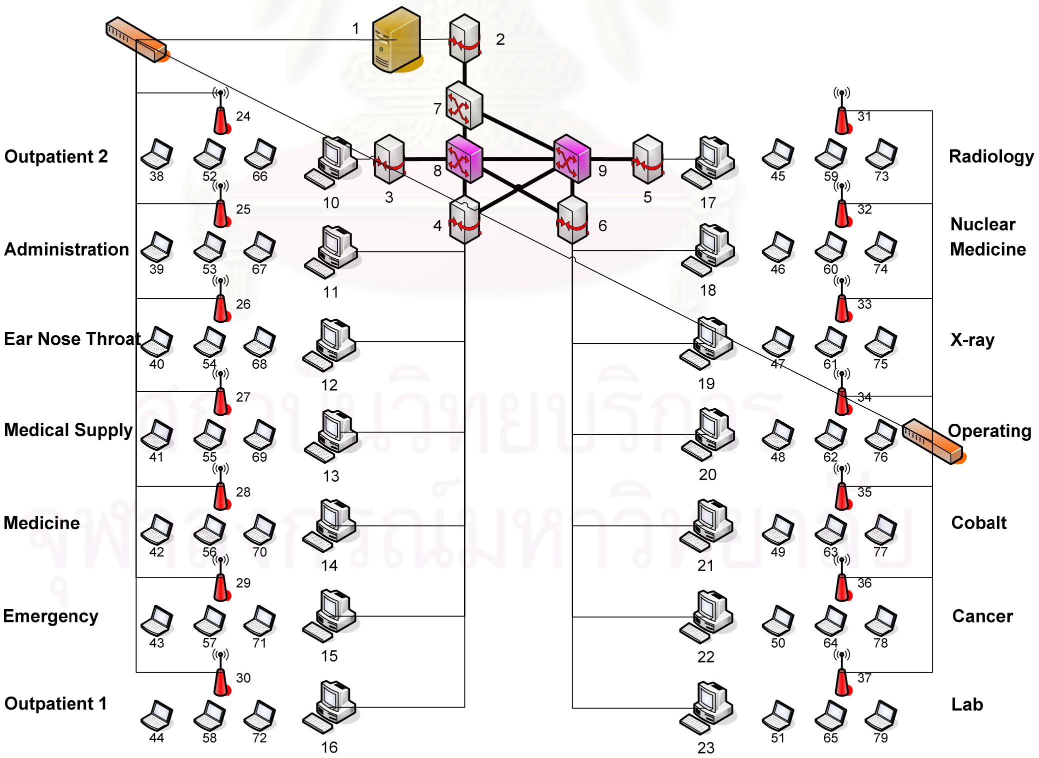

Figure 3.6: Overlap-network with policies

• *Network Architecture*

In this architecture, a wired network was unchanged, as mentioned in the Current-network, except that every building is installed a wireless network (IEEE 802.11g), and also set up a suitable network management policies of both wired and wireless for improving the performance.

Details of this architecture are described as follow.

Wired: It is similar to the Current-network, except that it is added lines between servers and a Wi-Fi switch, between Wi-Fi switches, and between a Wi-Fi switch and access points due to installation of the wireless technology.

Wi-Fi: all wireless devices will communicate with a server (Node 1) via access points for obtaining information used in the hospital, or even Internet services. Thus, an access point, which is installed in each building, is represented in node 24-37.

Due to consideration of appropriate location in the real situation, there are 2 Wi-Fi switches which the first one is located in the Outpatient 2 building (near the server), while the second is located in the Operating building. Since there are 3 application types from wireless devices in this experiment, all wireless devices are divided into 3 categories: Node 38-51 represent wireless devices from doctors who would like patients' information for helping them diagnosis. Node 52-65 represent wireless devices from doctors who want to access Internet services, and Node 66-79 represent wireless devices from patients who want to surf over the Internet.

Although the Overlap-network with policies is installed a wireless network to mitigate a congestion problem occurred in the communication channel, it is required to manage applications that must be routed within in the system in order to enhance performance of this network. Therefore, suitable network management policies of both wired and wireless for this network are determined as follow.

Wired Policy: it was set up by considering ***an important of routine work in each building.*** In doing so, the highest priority is set for the buildings that provide medical treatment which is occasionally significant in vital or some tasks were required for the short delay time of an incoming message. Then, the middle priority is set for the buildings that their routine work involve in various kinds of applications or their information are sometimes need to transmit to doctors as requested. Lastly, setting up the lowest priority is for the buildings that used only data in their routine, or they are acceptable for the long delay time of incoming message. As a result, the wired policy for the Overlap-network is illustrated in Table 3.3.

Table 3.3: Wired Policy for the Overlap-network

Priority	Building
Highest	Outpatient 2, Administration, Ear Nose Throat, Emergency, Outpatient 1, and Operating
Middle	Radiology, Nuclear Medicine, X-ray, Cobalt, Cancer, and Lab
Lowest	Medical Supply, and Medicine

Wireless Policy: it was set up by considering the ***objectives and user types,*** which differs from the wired policy caused by the same reason as mentioned in the wired and Wi-Fi networks with policies. Especially, all priority levels of applications from wireless are under the lowest priority level of the wired policy due to avoidance of the full stack in the queue. Also, in this experiment, there are 3 types of applications, which are applications from patient information for doctors, Internet services for doctors, and Internet services for patients. Therefore, the wireless policy for the Overlap-network is illustrated in Table 3.4.

Table 3.4: Wireless policy for the Overlap-network

Priority	Type of Wi-Fi application
Highest	Patient information for doctors
Middle	Internet services for doctors
Lowest	Internet services for patients

• *Simulation Model Description*

The simulation of this architecture will compose of 2 parts:

Wired: A core network is ATM with 155 Mbps data rate, and access networks are Fast Ethernet in the full duplex mode, as mentioned in the Current-network. Due to the installation of Wi-Fi, it is required to link some components of wireless. For instance, Gigabit Ethernet is applied to link between a server and the Wi-Fi switch, and between Wi-Fi switches, while the Fast Ethernet is for linking between the Wi-Fi switch and access points.

Wi-Fi: IEEE 802.11g with 54 Mbps data rate is installed as the wireless network for each building. Although the data rate of this technology can be reach up to 54 Mbps, in theory, its typical throughput is about 20 Mbps. Thus, for 14 buildings, the overall wireless throughput is approximately 280 Mbps. So, some applications of patient information, which all have the data rate 20 Mbps, are split from wired and transmitted via Wi-Fi instead. To illustrate this point, 20 Mbps. of data rate is split from the entire system that has the offered loads as 50, 75, 100 and 125 Mbps, and then the wired network will transmit at 30, 55, 80, and 105 Mbps, respectively.

After transmitting patient information with the data rate of 20 Mbps. via Wi-Fi, it remains 260 Mbps. under the bandwidth of this wireless network. Therefore, this rest bandwidth is provided for Internet services for doctors and patients in each building of the hospital. As a result, the wireless applications can be separated into 3 flow types: Patient information for doctors with data rate 20 Mbps, Internet services for doctors with data rate 130 Mbps, and Internet services for patients with data rate 130 Mbps.

Especially, the number of precedence is applied to applications from each building of both wired and wireless networks due to the set up of the wired and wireless policies.

CHAPTER IV

EXPERIMENTAL RESULTS

This chapter illustrates the experimental results of both simulated architecture and real architectures in Section 4.1 and Section 4.2, respectively. The results include the channel utilization, overall throughput, department/building throughputs, wired delays, Wi-Fi throughputs, and Wi-Fi delays. In addition, these experimental results will be discussed in this chapter as well.

4.1 Simulated Architecture

Channel utilization of lines is firstly determined in order to find out the minimum time for simulation that loaded traffic is reached to the peak value. After specifying the proper simulation time, the simulated architectures were established and results are collected and calculated in order to evaluate performance of each network. Since throughput and delay time are main indicators of the network performance, therefore, overall throughput, department throughputs, wired delays, Wi-Fi throughputs, and Wi-Fi delays are analyzed.

To measure the network performance under various conditions, the offered load considered in this experiment can be classified in 3 main conditions. First is the condition that offered load is less than the maximum load or offered loads are 250, 500, 750 Mbps. Second is the condition that offered is equal to the maximum load or offered load is 1000 Mbps; and the last is the condition that offered load is greater than the maximum load or offered load is 1250 Mbps. Thus, all simulated architectures are offered the load at 250, 500, 750, 1000, and 1250 Mbps. for evaluating their performance.

4.1.1 Channel Utilization

In the simulation method, when the channel utilization of a line reached to the peak value, the line will also reach to its maximum that can support, and then system is stable or has a small change after this point. Thus, performance parameters, such as throughput, delay, or jitter, will also be constant.

Since the simulator cannot simulate the situation within the same period of the real world, the simulation time usually takes a longer time than the real case. For example, if the real measurement in the real system is 40 min, this measurement cannot be used directly to the simulator to obtain the simulation values; the simulator must work for a day to obtain the required case. Additionally, due to the fact that the channel utilization of a line depends on simulation time, it is required for the investigation of the channel utilization at various times to obtain the minimum simulation time. Consequently, the wired network of simulated architecture was investigated channel utilization by varying time. According to the result in Figure 4.1, it has shown that when the simulation time increased, the channel utilization will also increase until it reached to the maximum point, and then it will slightly deviate from this maximum value. Moreover, when the simulation time is 40 minutes, channel utilization begins to change slightly which the value is $6.868 * 10^{-3}$, and then the change is more slightly after this point. Therefore, it can be specified that 40 minutes is the minimum simulation time, and all the simulated architectures will be performed at this time as well.

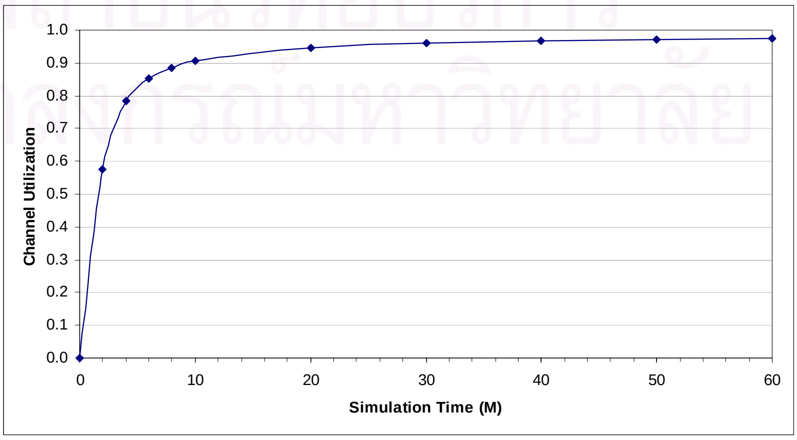

Figure 4.1: Channel Utilization of simulated architecture

4.1.2 Overall Throughput

In this experiment, the throughput loss rate of the overall system was compared in 4 network models, under the offered loads of the entire system are 250, 500, 750, 1000, and 1250 Mbps. According to Figure 4.2, the result has shown that the percentages of the loss rate in the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model are greater than the other models at the beginning when the offered load is less than 1 Gbps. On the other hand, it will be less than the others when the offered loads are equal to or greater than 1 Gbps. This is because when the offered load is less than 1 Gbps, the loss rate of the wired is less than the Wi-Fi. So, the loss rates of the entire system are high in both the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model due to the loss rate from the Wi-Fi. In contrast, the loss rate of the wired will increase rapidly when the offered loads are equal to, or grater than 1 Gbps. because it reaches to the maximum load of the line that can support. Therefore, the loss rate of the overall system in the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model will decrease because these 2 models are split some offered load to the Wi-Fi. Thus, the wired was not forced to support the entire load in the network.

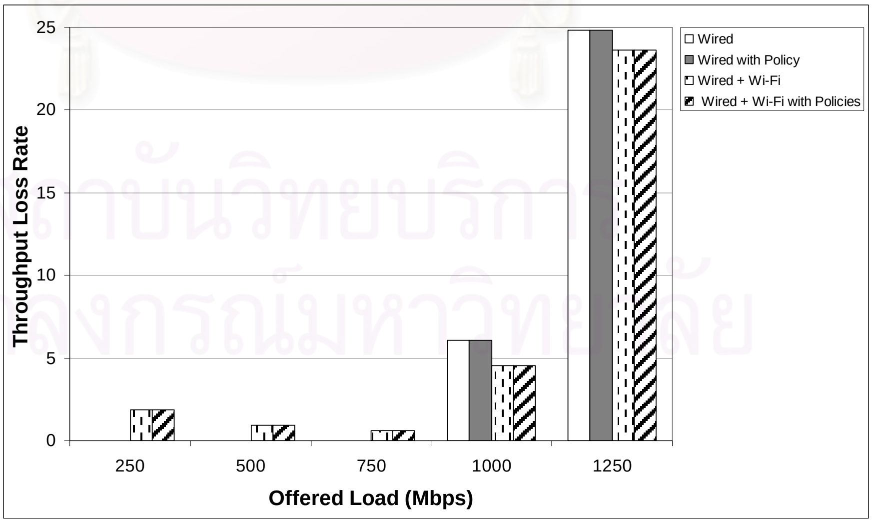

Figure 4.2: The average loss rate of the overall system in simulated architectures when offered loads of the entire system are 250, 500, 750, 1000, and 1250 Mbps.

4.1.3 Department Throughput

Although the overall throughput has shown that the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model can achieve the higher performance than others, the differences between applying with and without the wired policy cannot be noticeable in that result. Hence, the throughput loss rates occurred in each department of both Inpatient and Outpatient buildings are also determined.

Furthermore, when the offered loads of the entire system are 250, 500, and 750 Mbps, the line within the network can work properly due to the fact that it does not reach to the maximum load of the line. Thus, results of these offered loads can be discussed together. Consequently, the department throughput will be analyzed in 3 main conditions. The first is the condition that traffic load is less than the maximum load or the offered loads are 250, 500, and 750 Mbps. The second is the condition that traffic load is equal to the maximum load or the offered load is 1000 Mbps. The last is the condition that traffic load is greater than the maximum load or the offered load is 1250 Mbps.

• ***250, 500, and 750 Mbps.***

Referring to the Inpatient building, the result of throughput loss rate in each department when the offered load of the entire system is 250, 500, and 750 Mbps, are illustrated in Figure 4.3, 4.5, and 4.7, respectively. Since the wired has a smaller number of loss rates than the Wi-Fi when offered loads is less than the maximum, so only the percentage of loss rates from the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model can be noticeable under this condition. Furthermore, the throughput loss rates in the wired and Wi-Fi networks model is related to FIFO of the queue type, which is lowest in the emergency room and then reaches to the highest one in the Inpatient 2 departments, due to no policy. On the other hand, the percentage of the loss rate in the wired and Wi-Fi networks with policies model is the lowest in the emergency room, rises in the rehabilitation department, and then reaches to the highest in the remaining departments. Moreover, according to the results, when the offered increased, the throughput loss rate will decrease because the offered loads are less than the maximum load of the line in this condition, so that a line can handle its transmitted applications, and the loss will be reserved in this condition. For that reason, when increase the offered load, the throughput loss rate will decrease.

For the Outpatient building, the result of throughput loss rate in each department when the offered load of the entire system is 250, 500, and 750 Mbps, are illustrated in Figure 4.4, 4.6, and 4.8, respectively. As mentioned, only the percentage of loss rates from the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model can be noticeable in this condition. Likewise, the throughput loss rate in the wired and Wi-Fi networks model is related to FIFO of the queue type, which is the lowest in the medical record department and then reaches to the highest one in the laboratory department, due to no policy. For the wired and Wi-Fi networks with policies model, the average loss rate is the lowest in the medical record, rises in the pharmacy department, and reaches to the highest in the remaining departments. Additionally, when the offered increased, throughput loss rate will decrease as same as the previous one.

According to the Figure 4.3-4.8, throughput loss rate in the wired and Wi-Fi networks model is related to FIFO of the queue type, which is the lowest in the first department and then reaches to the highest one in the last department, due to no policy. While the percentage of the loss rate in the wired and Wi-Fi networks with policies model is not consistent with the wired policy, it is the lowest in the first department, rises in the second, and reaches to the highest in the remaining departments. This is because the traffic load is not reached to the maximum of the line in this condition. So, the system can continue managing transmitted applications. Thus, applying the policy at this point does not influence as intended.

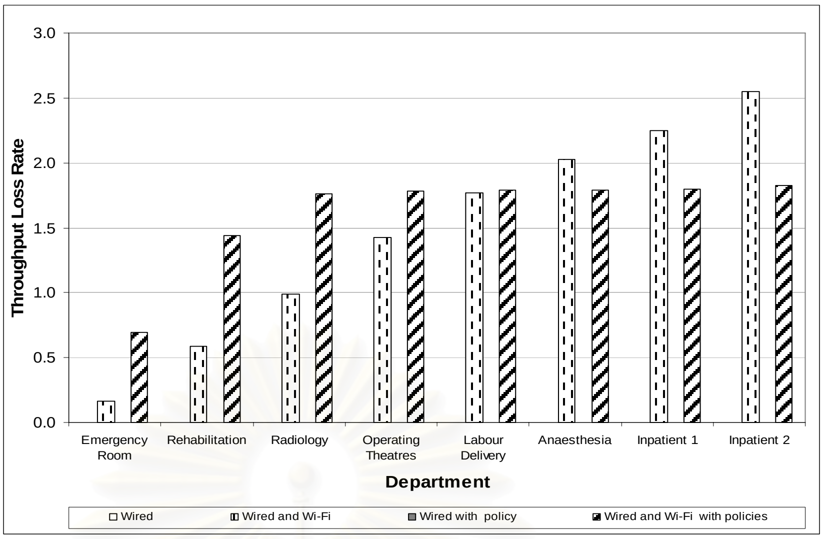

Figure 4.3: The average loss rate of each department in the Inpatient building when the offered load of the entire system is 250 Mbps.

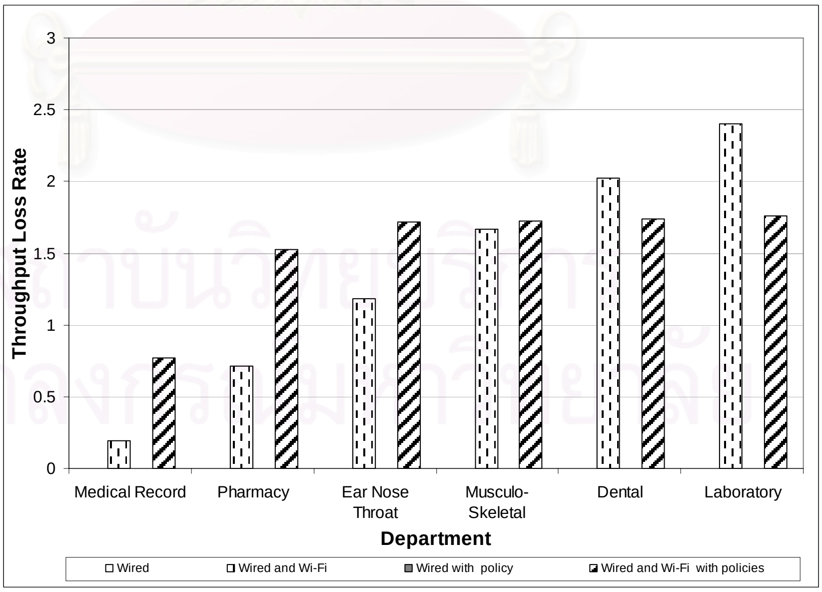

Figure 4.4: The average loss rate of each department in the Outpatient building when the offered load of the entire system is 250 Mbps.

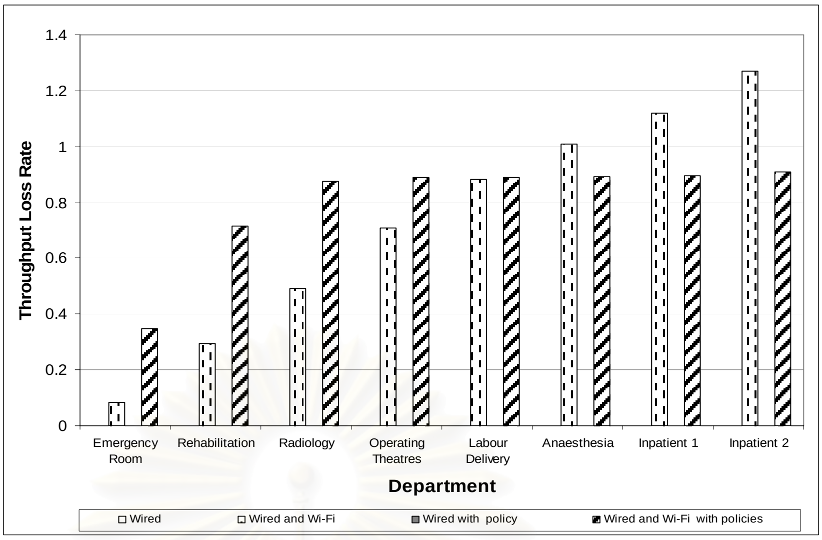

Figure 4.5: The average loss rate of each department in the Inpatient building when the offered load of the entire system is 500 Mbps.

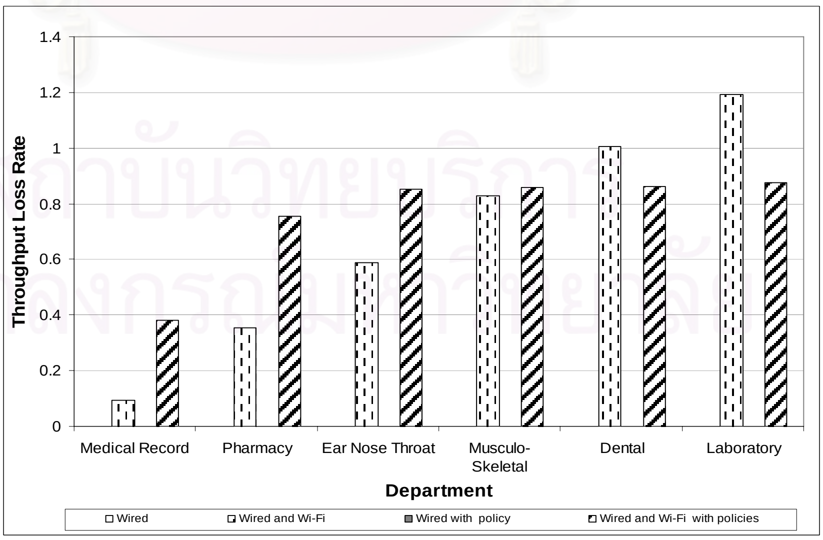

Figure 4.6: The average loss rate of each department in the Outpatient building when the offered load of the entire system is 500 Mbps.

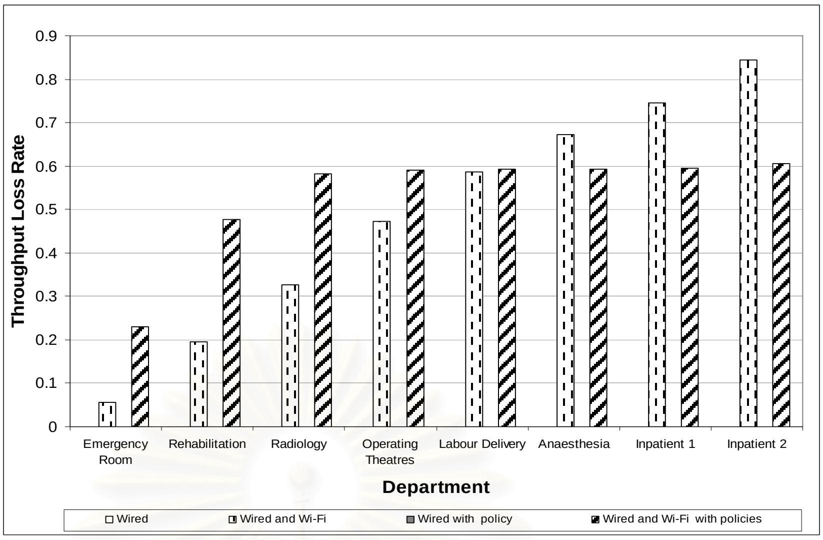

Figure 4.7: The average loss rate of each department in the Inpatient building when the offered load of the entire system is 750 Mbps.

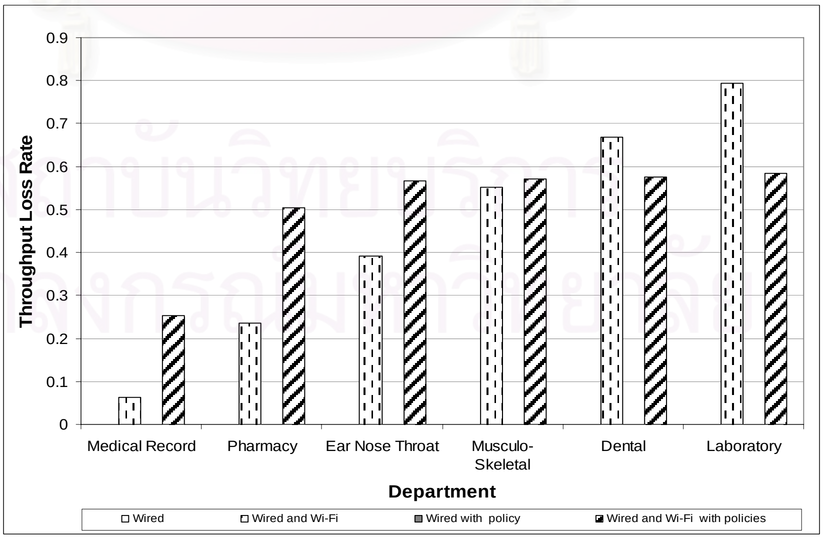

Figure 4.8: The average loss rate of each department in the Outpatient building when the offered load of the entire system is 750 Mbps.

• *1000 Mbps.*

According to Figure 4.9-4.10, the loss rate of each department in the wired network model, and the wired and Wi-Fi networks model increase rapidly in the last departments, which are Inpatient 2 for the Inpatient building and Laboratory for the Outpatient building, while it is very low in the remaining departments because there is no policy in these models. Therefore, when the load reaches to the maximum value of the line, applications for the last departments are blocked by the former departments due to First In First Out (FIFO) of queue type. In contrast, throughputs in the wired network with policy model, and the wired and Wi-Fi networks with policies model are extremely loss in the lowest priority departments, which are Inpatient 2 in the Inpatient building and Pharmacy in the Outpatient building, because of applying the wired policy in these models. Additionally, when comparing the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model to the others, the results have shown that installation of the wireless can efficiently relieve the loss of throughputs in the high traffic load.

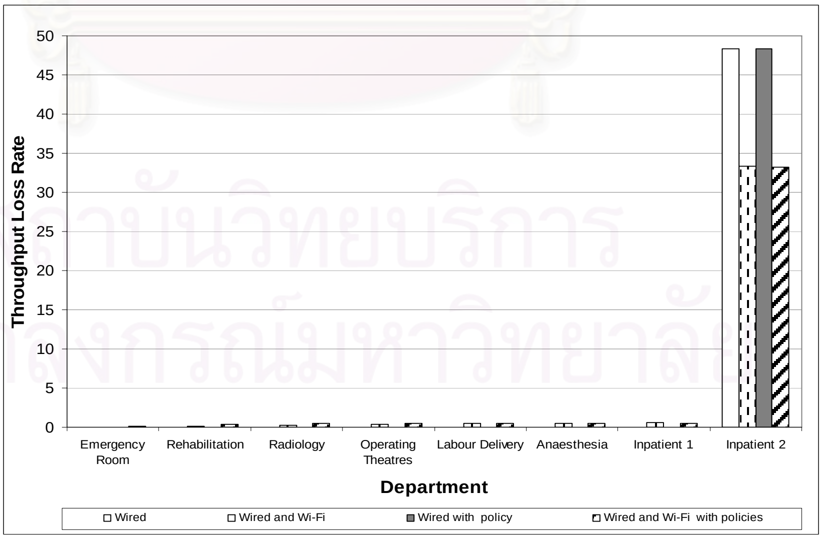

Figure 4.9: The average loss rate of each department in the Inpatient building when the offered load of the entire system is 1000 Mbps.

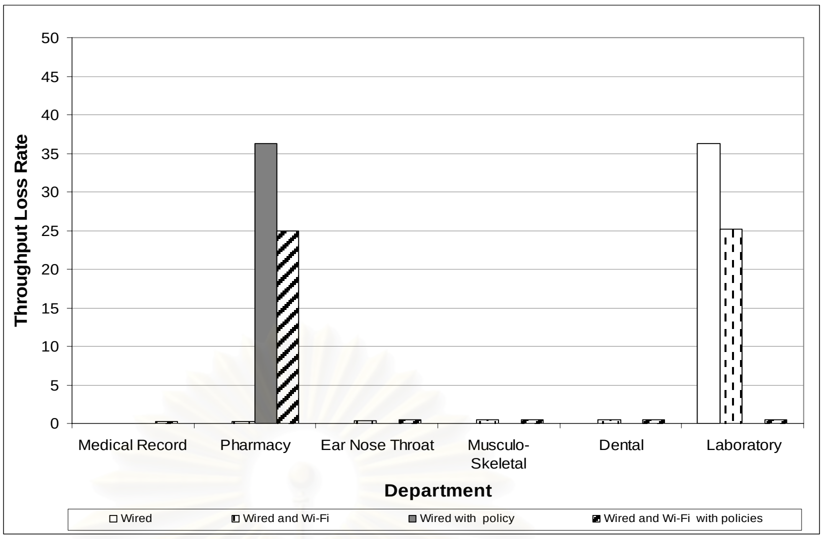

Figure 4.10: The average loss rate of each department in the Outpatient building when the offered load of the entire system is 1000 Mbps.

• 1250 Mbps.

Since this condition is also offered high traffic load to the network, results correspond to the one with 1000 Mbps. Similarly, the throughput loss rate is greater than that of 1000 Mbps. due to more traffic load. From Figure 4.11-4.12, a great number of throughputs in the wired network model and in the wired and Wi-Fi networks model are lost in the last two departments due to FIFO of the queue types and no policy in these two models. In the other words, other models applied the wired policy are lost in two departments of the lowest priority level. Accordingly, in the wired network with policy model and the wired and Wi-Fi networks with policies model, there are a great number of the throughput loss rates in the Inpatient 1 and 2 of Inpatient building, and in the Medical record and the Pharmacy of Outpatient building. Moreover, these results also show that the installation of the wireless help reducing the throughput loss rate in spite of congestion occurred in communication channel.

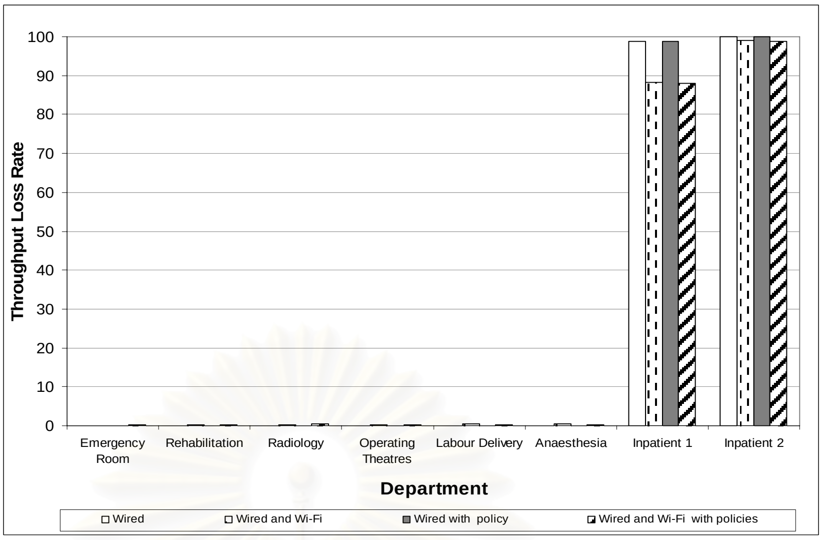

Figure 4.11: The average loss rate of each department in the Inpatient building when the offered load of the entire system is 1250 Mbps.

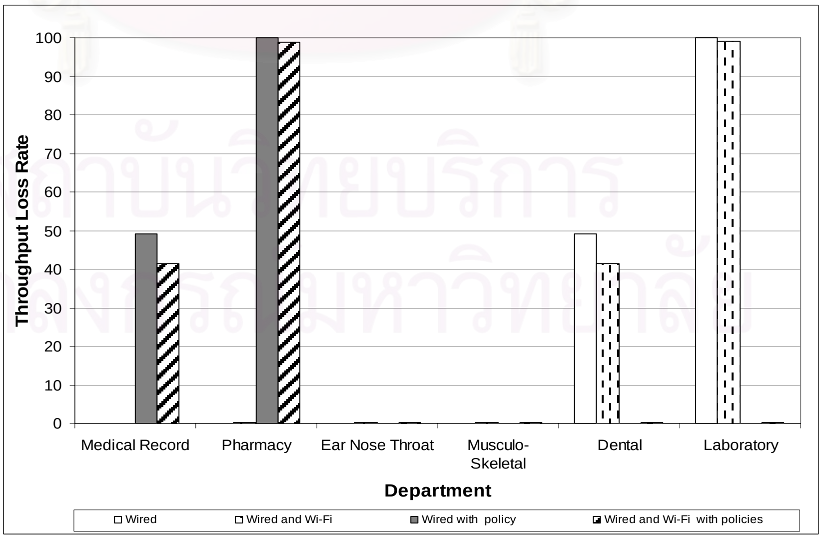

Figure 4.12: The average loss rate of each department in the Outpatient building when the offered load of the entire system is 1250 Mbps.

4.1.4 Wired Delay

The delay time is not only an important parameter that is indicated the network performance, but it is also very critical in the Medicare system. Especially, the long delay time of incoming message can harm patients' life and die in the emergency cases. Therefore, it is necessary to determine the delay time of applications that must be routed over the entire system.

For the wired, the policy was setting up by considering needs in each department. Consequently, the average delay per throughput of transmitted application from each department of both Inpatient building and Outpatient building is considered in order to distinguish between applying the policy and without applying it.

As mentioned, it can be combined results from the offered load 250, 500, and 750 Mbps together because all are the condition that the load is less than the maximum of line. As similar to the throughput, the wired delay of this experiment can be divided into 3 main conditions as follow.

• ***250, 500, and 750 Mbps.***

In Figure 4.13 - 4.18, the results have shown that the delay per throughput will continuously increase from the first to the last department of both Inpatient building and Outpatient building in case of the wired network model, including the wired and Wi-Fi networks model, due to First In First Out (FIFO) in the queue type and no policy. In other words, in the case of applying the policy, the delay per throughput is reduced in the highest priority departments, rose in the middle priority departments, and reached to the high value in the lowest priority departments. Furthermore, when comparing between the models cooperated with the wireless and without it, it is found that the delay per throughput of the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model is slightly greater than that of the wired network model and the wired network with policy model, respectively.

Despite the facts that the delay time of the wired network model is close to the wired and Wi-Fi networks model, throughput of each model is different so that delay per throughput, which are quotients, is different too. Moreover, the results of the wired network with policy model, and the wired and Wi-Fi networks with policies model are in the same direction as the pervious one.

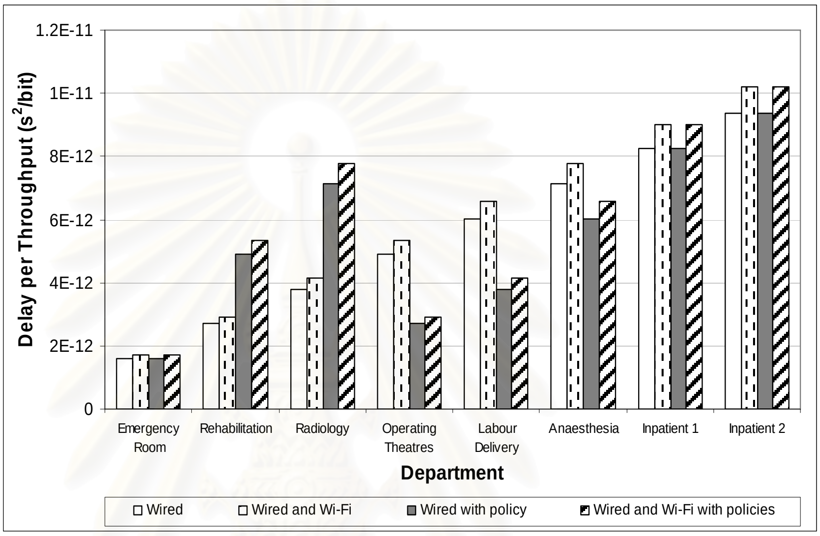

Figure 4.13: The average delay per throughput of each department in the Inpatient building when the offered load of the entire system is 250 Mbps.

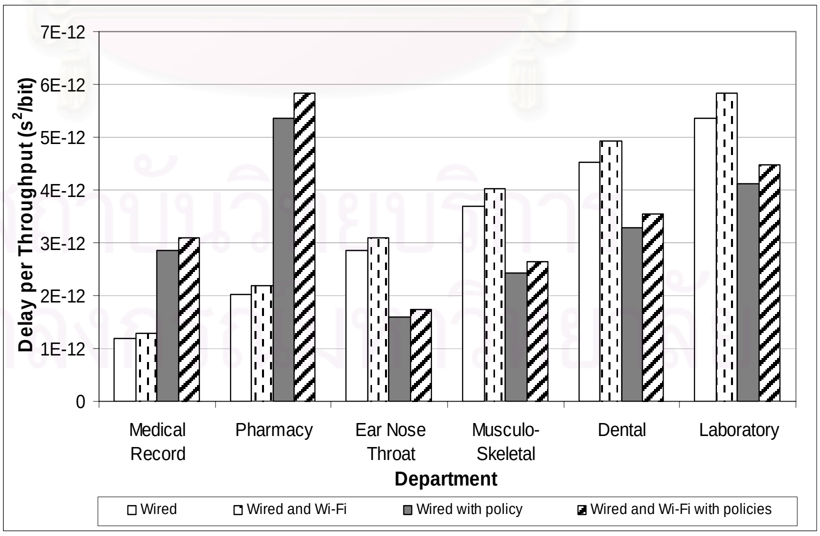

Figure 4.14: The average delay per throughput of each department in the Outpatient building when the offered load of the entire system is 250 Mbps.

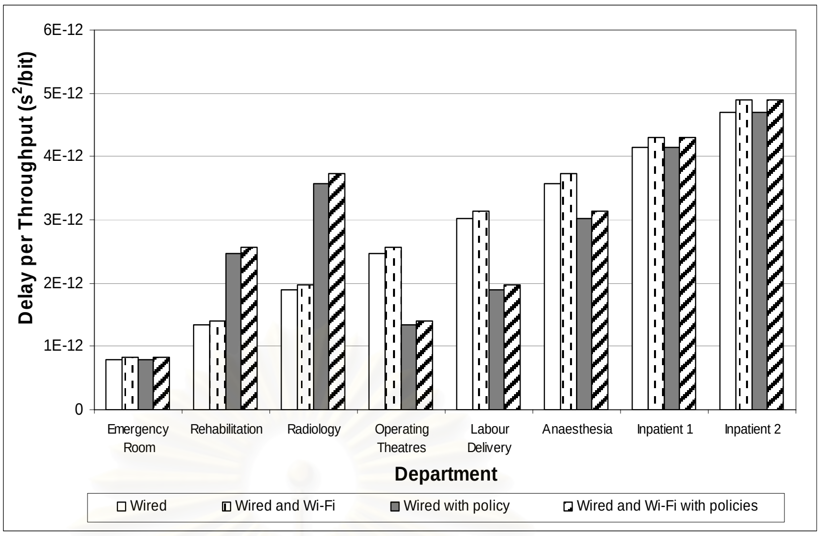

Figure 4.15: The average delay per throughput of each department in the Inpatient building when the offered load of the entire system is 500 Mbps.

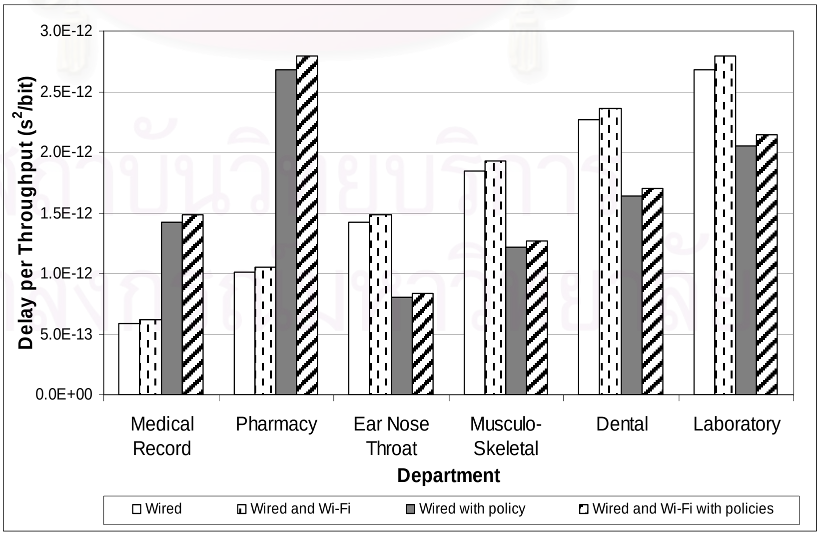

Figure 4.16: The average delay per throughput of each department in the Outpatient building when the offered load of the entire system is 500 Mbps.

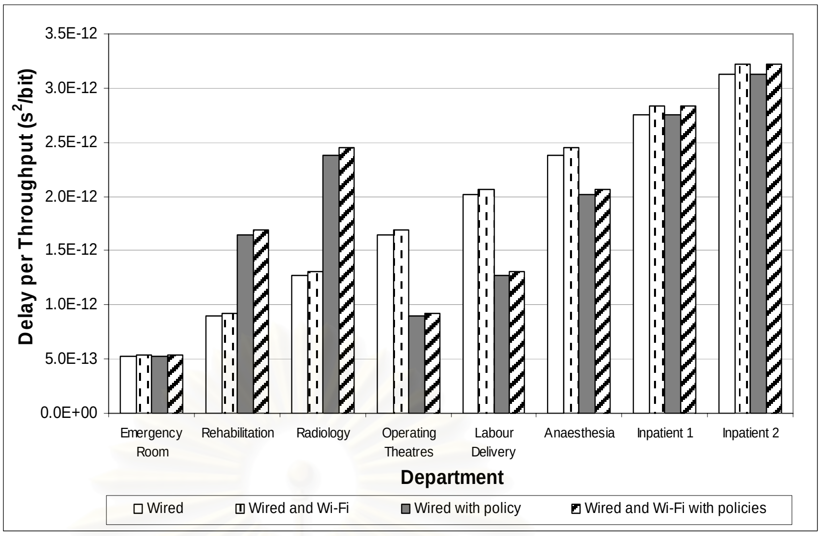

Figure 4.17: The average delay per throughput of each department in the Inpatient building when the offered load of the entire system is 750 Mbps.

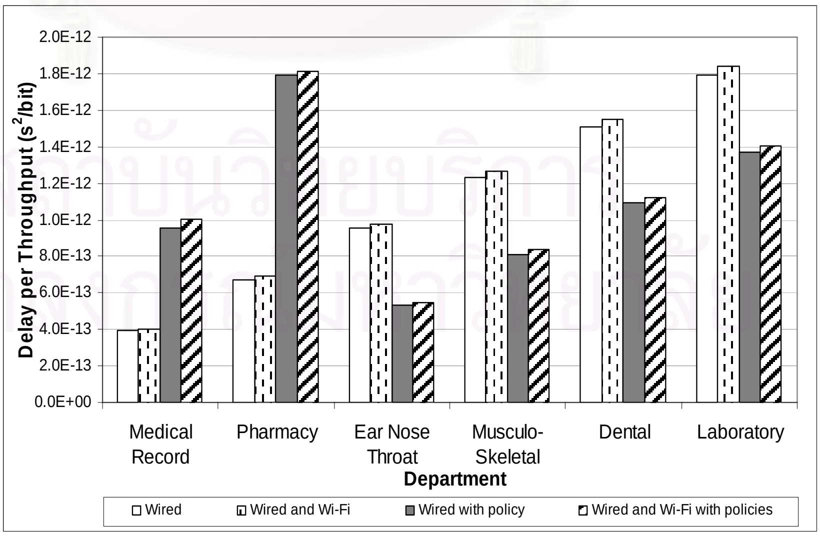

Figure 4.18: The average delay per throughput of each department in the Outpatient building when the offered load of the entire system is 750 Mbps.

• *1000 Mbps.*

According to Figure 4.19 - 4.20, it has shown that applying the wired policy can efficiently reserve short delay time for the highest and the middle priority departments in a high traffic load, while the delay time will increase in the lowest priority department. In addition, this value also increased from the one at the load of 750 Mbps. In the wired network model and the wired and Wi-Fi networks model, the delay per throughput is greater than that of the middle, and the highest priority departments in the other models, and is closed to each other due to no policy in these 2 models. On the other hand, the results have shown that the delay per throughput in the wired network with policy model, and the wired and Wi-Fi networks with policies model are very low in the middle and the highest priority departments while it raises rapidly in the lowest priority departments due to reserving the short delay time for the higher priority departments. Furthermore, the delay per throughput of the wired and Wi-Fi networks with policies model is slightly decreased from that of the wired network with policy model because of spitting some load to Wi-Fi.

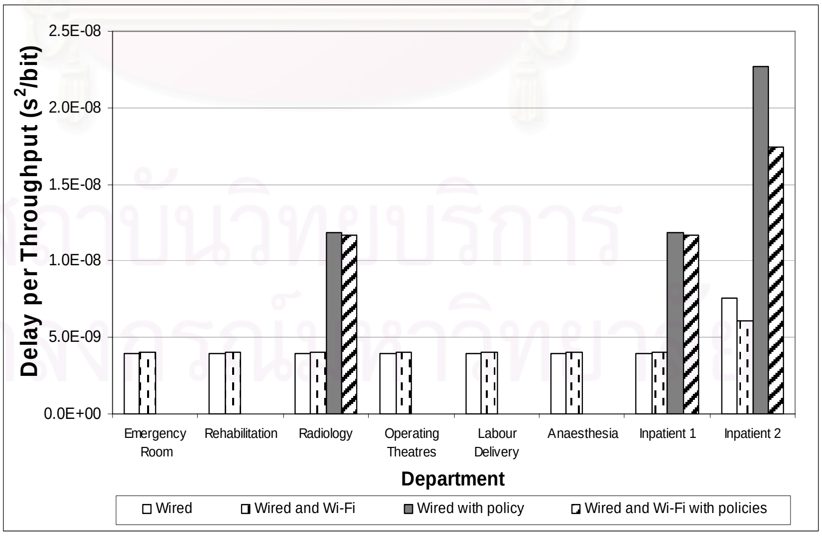

Figure 4.19: The average delay per throughput of each department in the Inpatient building when the offered load of the entire system is 1000 Mbps.

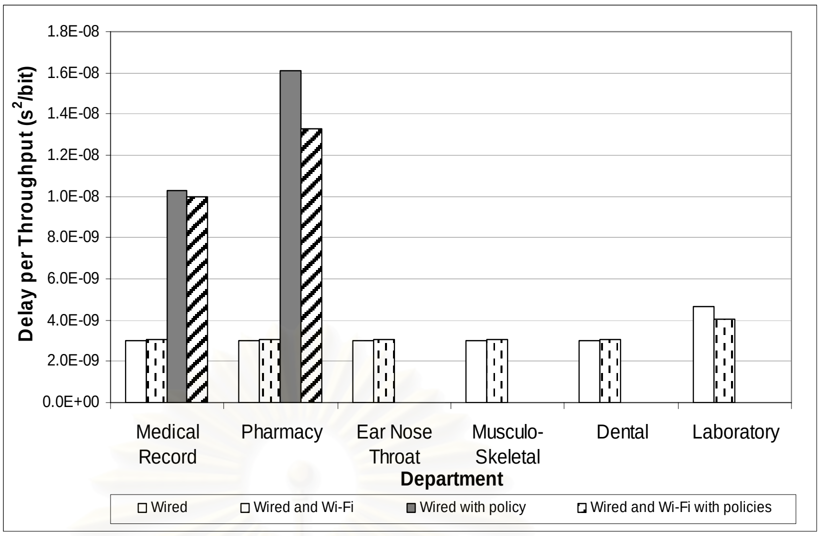

Figure 4.20: The average delay per throughput of each department in the Outpatient building when the offered load of the entire system is 1000 Mbps.

• *1250 Mbps.*

When the offered load is 1250 Mbps, the results are consistent with the ones with 1000 Mbps load, except that the values are higher, as shown in Figure 4.21 - 4.22. Even though, the load is greater than the maximum value of line that can support, the wired network with policy model, and the wired and Wi-Fi networks with policies model can efficiently reserve the short delay for the middle and the highest priority departments. Especially, the wired and Wi-Fi networks with policies model can also decreased the delay per throughput for transmitted applications even in the lowest priority department, when compared to the wired network with policy model.

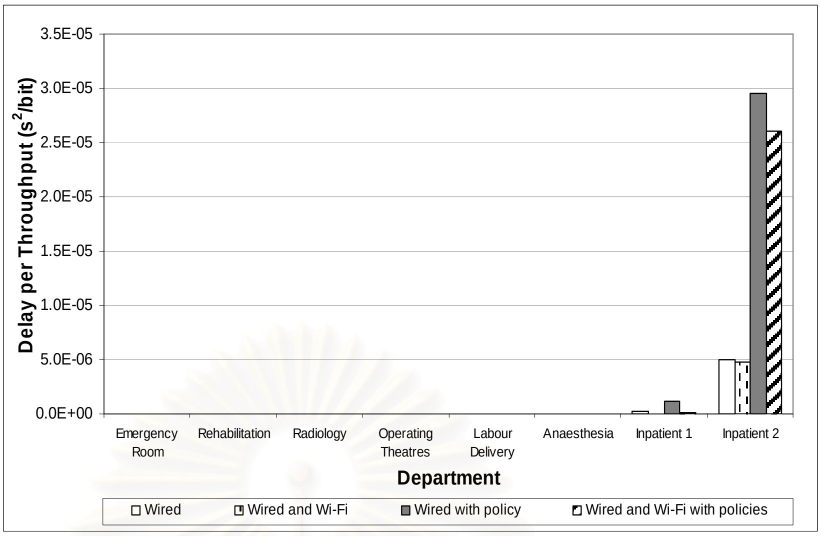

Figure 4.21: The average delay per throughput of each department in the Inpatient building when the offered load of the entire system is 1250 Mbps.

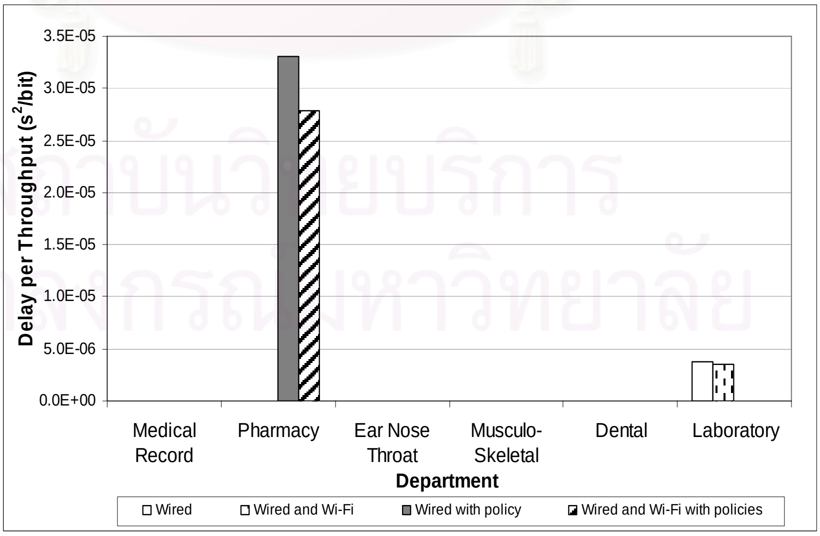

Figure 4.22: The average delay per throughput of each department in the Outpatient building when the offered load of the entire system is 1250 Mbps.

4.1.5 Wi-Fi throughput

Since the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model are installed the wireless network, therefore, the throughput loss rates of the wireless in these 2 models are determined.

Figure 4.23 – 4.24 have shown that when the wireless policy is not applied, the throughput from the wireless network is lost in every flow type of the wired and Wi-Fi networks model. In contrast, when applying the wireless policy, there is no loss of the throughput in the highest as well as the middle priority flows, which are the flow of patient information for doctors, and the Internet for doctors, while a great number of throughputs are lost in the lowest priority or in the flow of the Internet for patients. Consequently, it can be seen that applying this policy can support transmitting the significant wireless applications which is critical in patients' life. Despite the fact that the flow of the Internet for patients has a great number of throughput loss rates, the hospital can provides Internet services for entertaining their patients, while they are waiting for diagnosis, as an optional service.

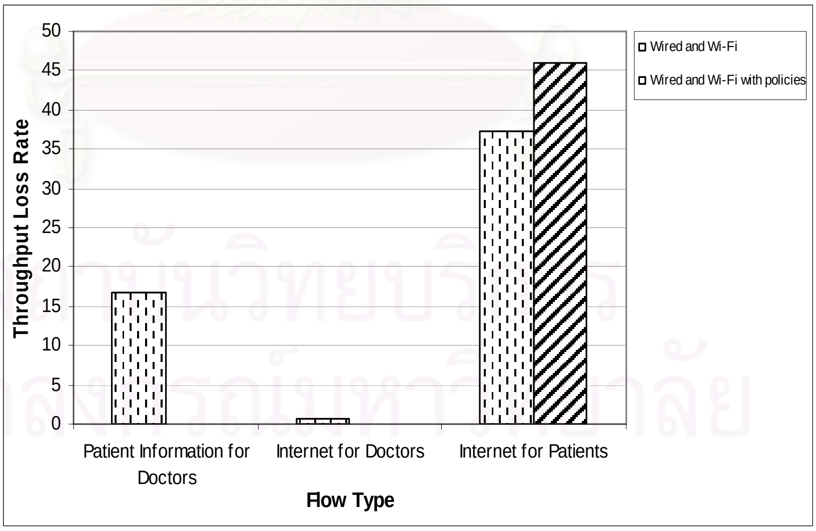

Figure 4.23: The average loss rate of each wireless flow type in the Inpatient building when the offered loads of Patient Information for doctors, the Internet for doctors, and the Internet for patients are 5 Mbps, 5 Mbps, and 10 Mbps, respectively

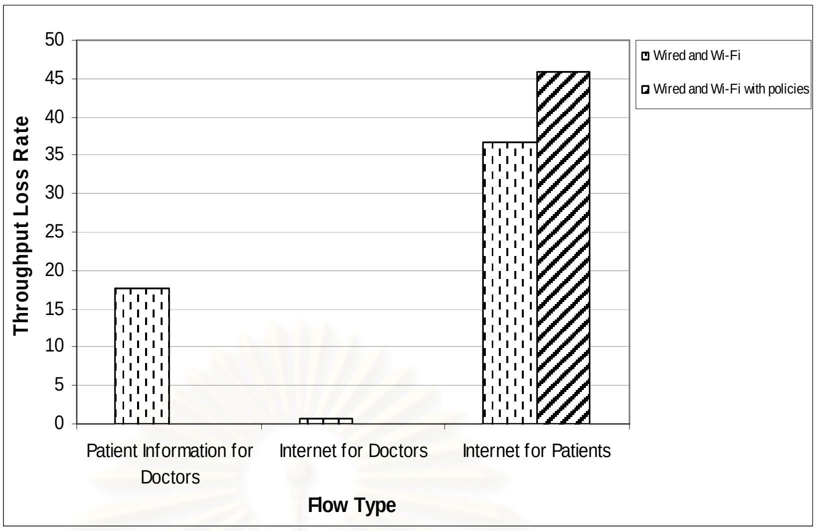

Figure 4.24: The average loss rate of each wireless flow type in the Outpatient building when the offered loads of Patient Information for doctors, the Internet for doctors, and the Internet for patients are 5 Mbps, 5 Mbps, and 10 Mbps, respectively

4.1.6 Wi-Fi Delay

For Wi-Fi, the policy was setting up by considering the objectives and user types. Then, the delay per throughput of Wi-Fi in both of Inpatient building and Outpatient building will be considered in order to distinguish each flow type of the model applied with the policy from the one without it.

According to Figure 4.25 and 4.26, the results have shown that the delay per throughput in every flow of the wired and Wi-Fi networks is close to each other because of no policy in this model, while the flow of patient information, which is served for doctors and also involved in transmitting significant information, in the wired and Wi-Fi networks with policies model can achieve very low delay per throughput as well as in the flow from doctors who would like to surf the Internet or even access the e-services. Although the delay per throughput from the flow of the Internet for patients has increased, this value is still close to that of the wired and Wi-Fi networks model. So, the hospital can provide Internet services to its patients while they are waiting for diagnosis.

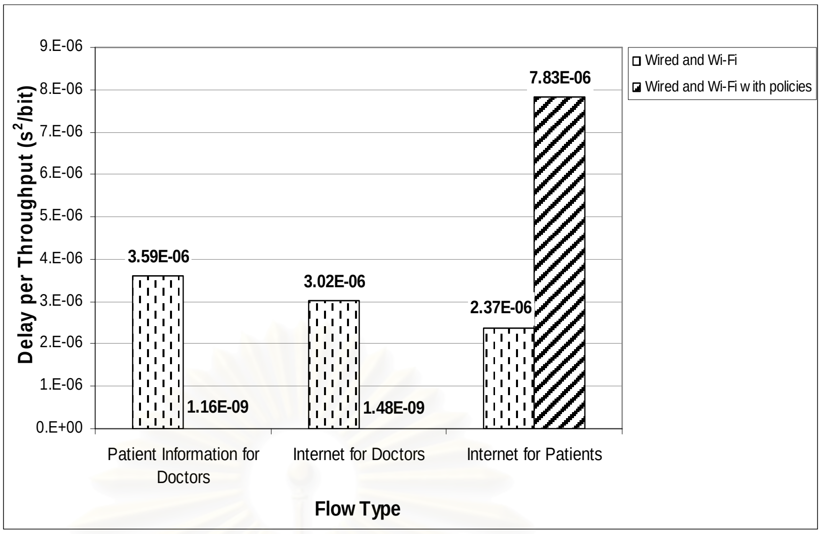

Figure 4.25: The average delay per throughput of each wireless flow type in the Inpatient building when the offered loads of Patient Information for doctors, the Internet for doctors, and the Internet for patients are 5 Mbps, 5 Mbps, and 10 Mbps, respectively

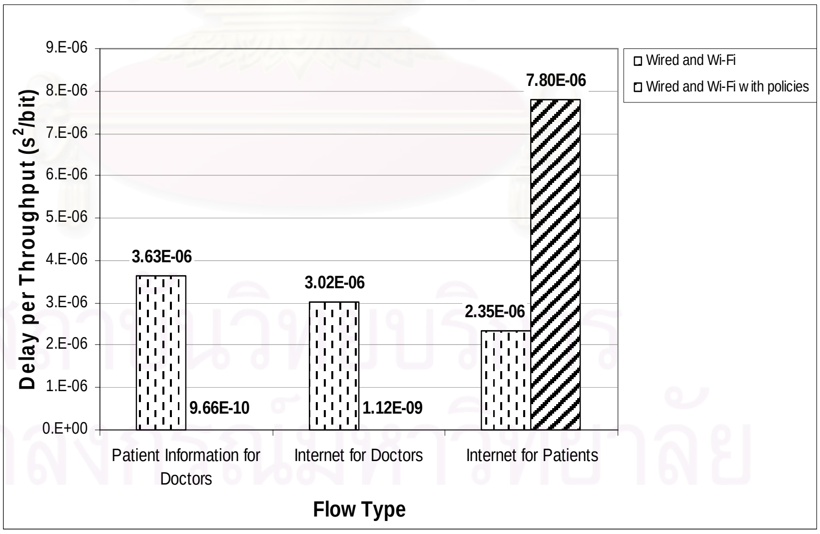

Figure 4.26: The average delay per throughput of each wireless flow type in the Outpatient building when the offered loads of Patient Information for doctors, the Internet for doctors, and the Internet for patients are 5 Mbps, 5 Mbps, and 10 Mbps, respectively

4.2 Real Architecture

This experiment begins with specifying an appropriate simulation time by detecting the channel utilization at various times. Then, all real architectures will be simulated at this appropriate time followed by collecting their experimental results. Finally, these results, which are overall throughputs, building throughputs, wired delays, Wi-Fi throughputs, and Wi-Fi delays, will be analyzed in order to measure performance of each model.

This experiment divides offered load served for the routine works in the hospital into 3 main conditions. Firstly, the condition that offered load is less than the maximum or where the ratios of offered load to the maximum load stand at 1:2 and 3:4. Secondly, the condition that offered load is equal to the maximum or where the ratio of offered load to the maximum load stands at 1:1. Lastly, the condition that offered load is greater than the maximum or where the ratio of offered load to the maximum load stands at 5:4. Thus, the network performance can be evaluated at various conditions.

Therefore, all real architectures, which consist of Current-network, Upgrade-network, and Overlap-network with policies, will be offered the ratios of load served for the routine works in the hospital to the maximum load at 1:2, 3:4, 1:1, and 5:4.

4.2.1 Channel Utilization

As mentioned, the system will be stable after the channel utilization has reached to its maximum value, and then performance parameters, such as throughput, delay, and jitter, are constant. Since the channel utilization depends on the simulation time, the investigation of the channel utilization at various times is required in order to detect the minimum simulation time that the channel utilization has reached to its maximum. Therefore, the channel utilization of Current-network is investigated by varying times. From Figure 4.27, the result has shown that the channel utilization will increase sharply at the beginning and then rise moderately. Until the simulation time is 40 minutes, the channel utilization begins to change slightly which value is $6.869 * 10^{-3}$. Thus, it can be specified that 40 minutes is the first point that the channel utilization begins to reach to its maximum. Accordingly, all of the real architectures, which include Current-network, Upgrade-network, and Overlap-network with policies, will be simulated at 40 minutes.

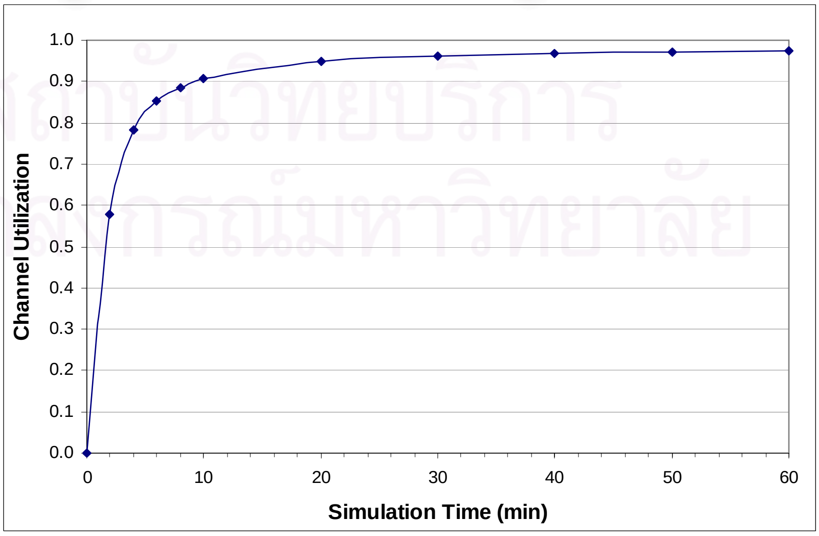

Figure 4.27: Channel Utilization of real architecture

4.2.2 Overall Throughput

The comparison of average throughput loss rate of the overall system in real architectures, where the ratios of offered load served for the main task in the hospital to the maximum load stand at 1:2, 3:4, 1:1, and 5:4, is shown in Figure 4.28. Where the ratios of offered load to the maximum stand at 1:2 and 3:4, there are no throughput loss rates from Current-network and Upgrade-network because the offered load is less than the maximum load, while the throughput from Overlap-network with policies is slightly lost due to the loss rate from Wi-Fi. In contrast, when the offered loads are increased, which the ratios are 1:1 and 5:4, the throughput loss rate of the wired network in Current-network as well as Upgrade-network is high because the offered load is greater than the maximum that the line can support. In other words, the throughput loss rate in Overlap-network with policies is very low. This is because Overlap-network with policies is well-managed in transmitted applications through the wired and wireless policies in addition to considering of resource allocation by installation of the wireless network. Thus, it can efficiently reduce the throughput loss rate of the overall system even in a high traffic load.

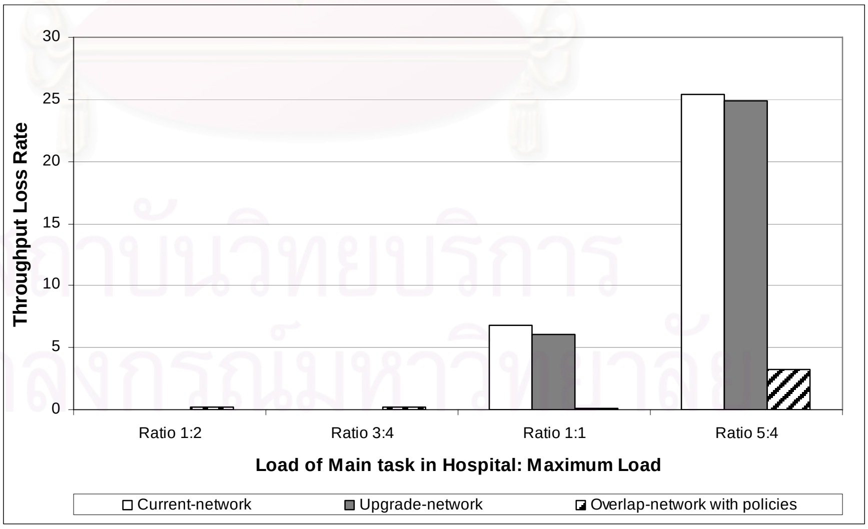

Figure 4.28: The average loss rate of the overall system in real architectures where the ratios of offered loads to the maximum load stand at 1:2, 3:4, 1:1 and 5:4

4.2.3 Building Throughput

Although Overlap-network with policies can achieve the minimum throughput loss rate of the overall system, it is not explicitly illustrated the impact of the wired policy to this model. Hence, it is required to determine the throughput loss rate occurred in each building.

Accordingly, in this experiment, the analysis of the throughput loss rate in each building is also divided into 3 main conditions. First is the condition that the offered load is less than the maximum load that line can support, or where the ratios stand at 1:2 and 3:4. Second is the condition that the offered load is equal to the maximum, or where the ratio stands at 1:1. The last is the condition that the offered load is greater than the maximum, or where the ratio stands at 5:4.

• *Ratio 1:2 and Ratio 3:4*

The comparison of the average throughput loss rates in each building of real architectures, where the ratios of offered load served for the main task in the hospital to the maximum load stand at 1:2 and 3:4, are shown in Figure 4.29 and 4.30, respectively. From these results, there is no throughput loss rate in each building of Upgrade-network, while this value is slightly lost in Current-network and Overlap-network with policies. In Current-network, the throughput loss rate from each building is not consistent with the First In First Out of the queue types. Similarly, the throughput loss rate from each building of Overlap-network with policies is also not consistent with the prioritization of the wired policy. Therefore, it can be implied that throughputs from each building of both Current-network and Overlap-network with policies are randomly lost because the offered loads are less than the maximum of a line at this condition. So, the system can continue managing transmitted applications. Consequently, applying the proposed policy to Overlap-network at this condition does not influence as intended.

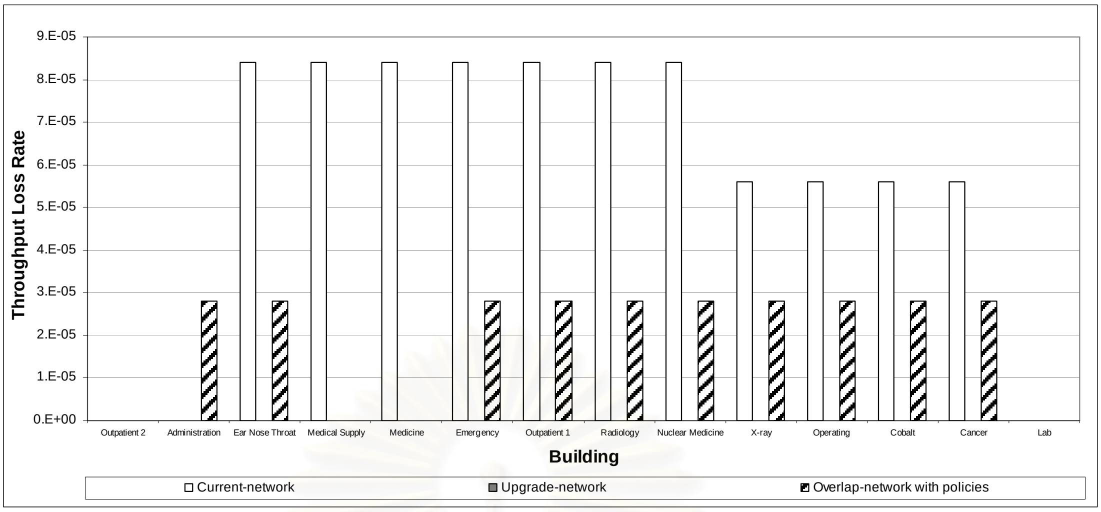

Figure 4.29: The average loss rate of each building in real architectures where the ratio of offered loads to the maximum load stands at 1:2

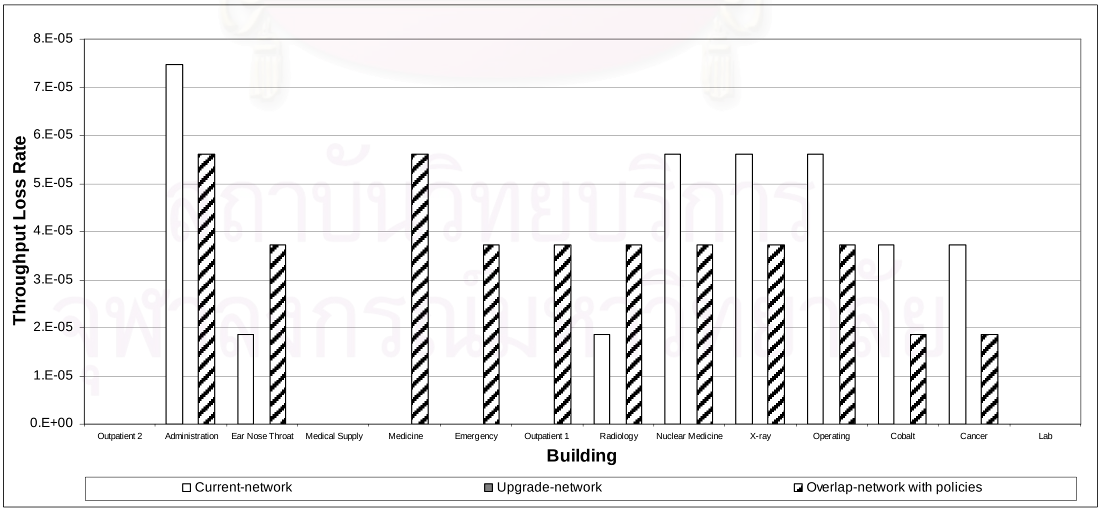

Figure 4.30: The average loss rate of each building in real architectures where the ratio of offered loads to the maximum load stands at 3:4

• *Ratio 1:1*

The comparison of the average throughput loss rates in each building of real architectures, where the ratio of offered load served for the main task in the hospital to the maximum load stand at 1:1, is shown in Figure 4.31. In Current-network and Upgrade- network, there are a great number of the throughput loss rates in the last building, which is the lab building, due to First In First Out (FIFO) of the queue types and no policy. Thus, when the load reaches to the maximum value of the line, transmitted applications for the last building are blocked by the former ones. In contrast, there is no throughput loss in every building of Overlap-network with policies due to appropriate management of the transmitted application through the proposed policy as well as considering of resource allocation by installing a wireless network to relieve the congestion problem. For this condition, the result has shown that applying the suitable network management policies to Overlap-network can efficiently prevent the loss of throughput in every building of the hospital, which applications must be routed within the Medicare system, and these transmitted applications are occasionally significant in patients' life.

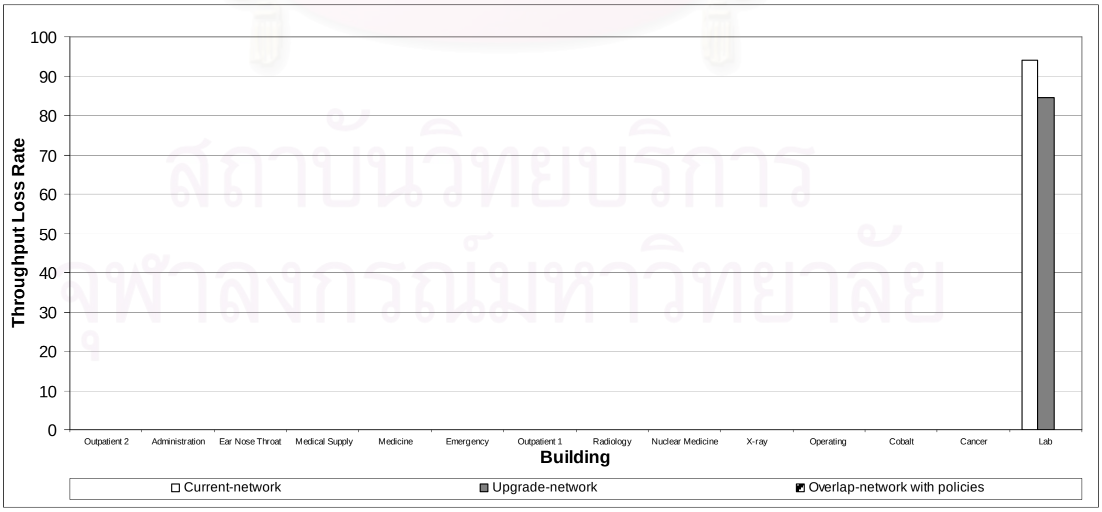

Figure 4.31: The average loss rate of each building in real architectures where the ratio of offered loads to the maximum load stands at 1:1

• *Ratio 5:4*

The comparison of the average throughput loss rates in each building of real architectures, where the ratios of offered load served for the main task in the hospital to the maximum load stand at 5:4, is shown in Figure 4.32. For this result, there are a great number of throughput loss rates in the last four buildings of both Current-network and Upgrade-network, while it is lost in the lowest priority buildings of the Overlap-network with policies. In Current-network and Upgrade-network, due to FIFO of the queue types and no policy, the throughput is extremely lost in the operating building, cobalt building, cancer building, and lab building, which the loss of throughput should be avoided for this kind of building, especially in the operating building. For instance, the routine work of operating building involves in surgery, therefore a loss of some transmitted applications can cause in patient's life, while the information from cobalt building, cancer building, and lab building is necessary for doctors to help them diagnosis, but the throughput is totally lost in these 3 buildings. In contrast, the loss of throughput is occurred in the medical supply building and the medicine building of Overlap-network with policies which the loss of throughput is not a serious problem in these two buildings, due to prioritization of the wired policy. Consequently, it can be noticed that although it is in the congestion situation, the loss of throughput in Overlap-network with policies is not only less than others, but it also occurred in the buildings that their routine work doesn't involve in patients' life.

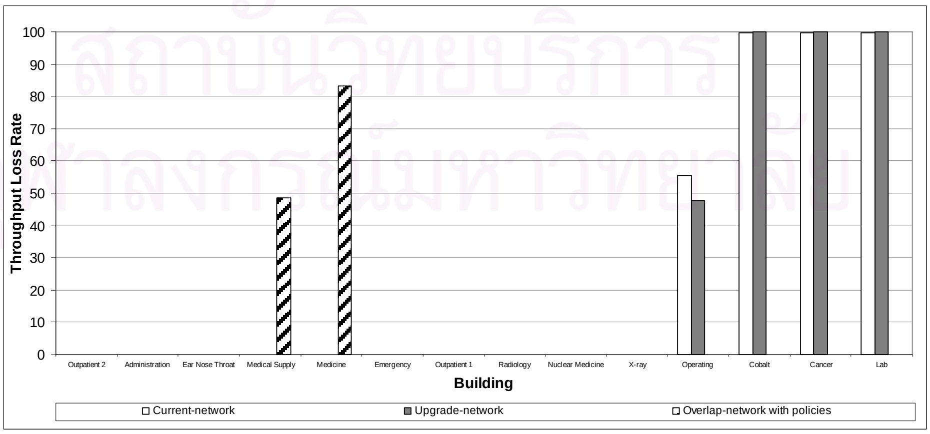

Figure 4.32: The average loss rate of each building in real architectures where the ratio of offered loads to the maximum load stands at 5:4

4.2.4 Wired Delay

Since the delay time of an incoming message is critical in the Medicare system, the delay time of transmitted applications is also analyzed in this experiment.

For Overlap-network, the wired policy applied to a wired network is determined by the essential of routine work in each building. On the other hand, there is no policy applied to Current-network and Upgrade-network. Therefore, this experiment distinguishes the model applied with the policy from the ones without it.

As mentioned, the results at the ratio 1:2 and 3:4 are also the condition that the offered load is less than the maximum so that they can be discussed together. Thus, the analysis of wired delay will be divided into 3 main conditions as follow.

• ***Ratio 1:2 and Ratio 3:4***

The comparison of the delay per throughput in each building of real architectures, where the ratios of offered load served for the main task in the hospital to the maximum load stand at 1:2 and 3:4, are shown in Figure 4.33 and 4.34, respectively. In Current-network and Upgrade-network, the delay per throughput continually increases from the first building to the last one due to FIFO of the queue types and no policy. Unfortunately, this value from Upgrade-network is very low when comparing to others. So, it cannot be seen in these figures, while this value from Current-network is slightly changed, so the change cannot be clearly noticed. In contrast, the delay per throughput from Overlap-network with policies is corresponded to the wired policy. Thus, it is low in the highest priority buildings, moderate in the middle priority buildings, and high in the lowest priority buildings. Since the offered load is less than the maximum, the system can keep managing transmitted applications. For that reason, applying the wired policy to Overlap-network at this condition does not influence obviously.

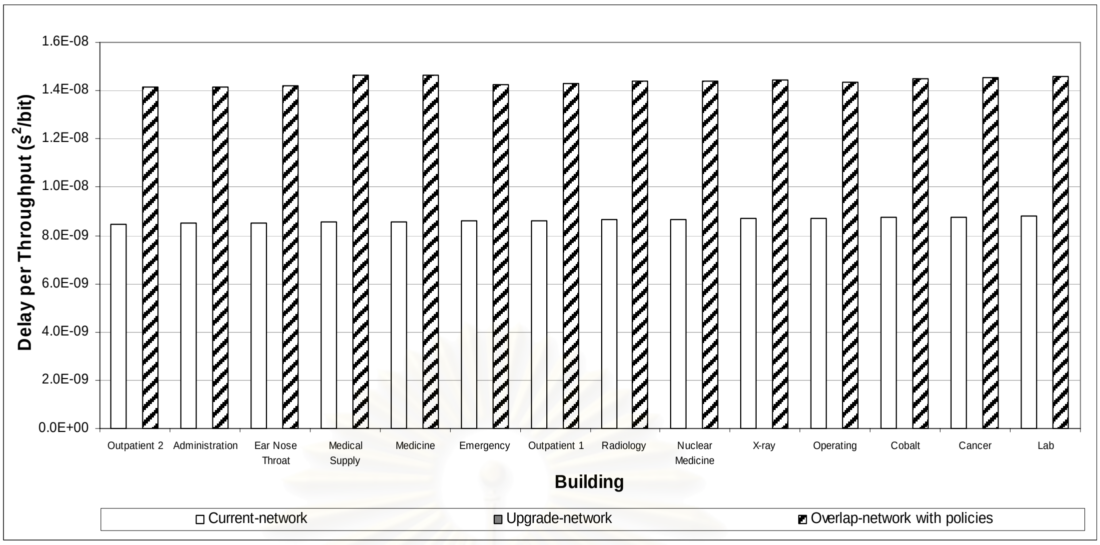

Figure 4.33: The average delay per throughput of each building in real architectures where the ratio of offered loads to the maximum load stands at 1:2

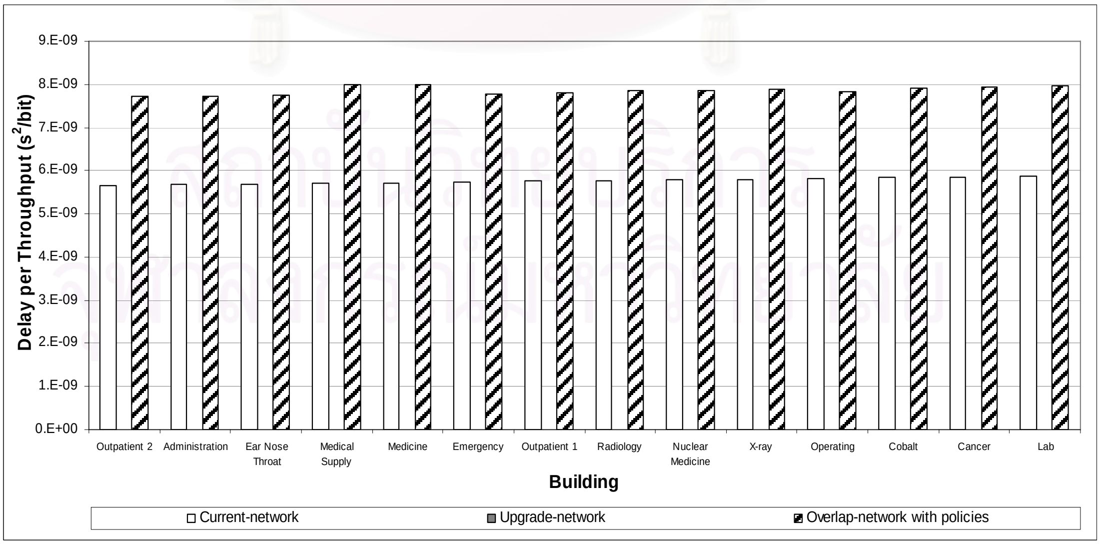

Figure 4.34: The average delay per throughput of each building in real architectures where the ratio of offered loads to the maximum load stands at 3:4

• Ratio 1:1

The comparison of the delay per throughput in each building of real architectures, where the ratios of offered load served for the main task in the hospital to the maximum load stand at 1:1, is shown in Figure 4.35. For this result, only the delay per throughput from Current-network can be seen in the figure because this value is very high when comparing to that from others. In Current-network and Upgrade-network, the results also continually increase from the first building to the last one due to FIFO of the queue types and no policy, according to the previous section. Moreover, they have been rapidly changed in the last building because they cannot hold on the overload of flow within the system. In Overlap-network with policies, the delay per throughput is still strictly corresponded to the wired policy. Therefore, this is low in the highest priority buildings, moderate in the middle priority buildings, and then high in the lowest priority buildings. Additionally, there is no rapid change of the delay per throughput in every building of this model. Moreover, this value is very low and also approaches to that from Upgrade-network as the fact that this Overlap-network with policies is well-managed in transmitted applications through the wired policy, and it also has the organization of resource allocation by installing the wireless network to mitigate the congestion problem.

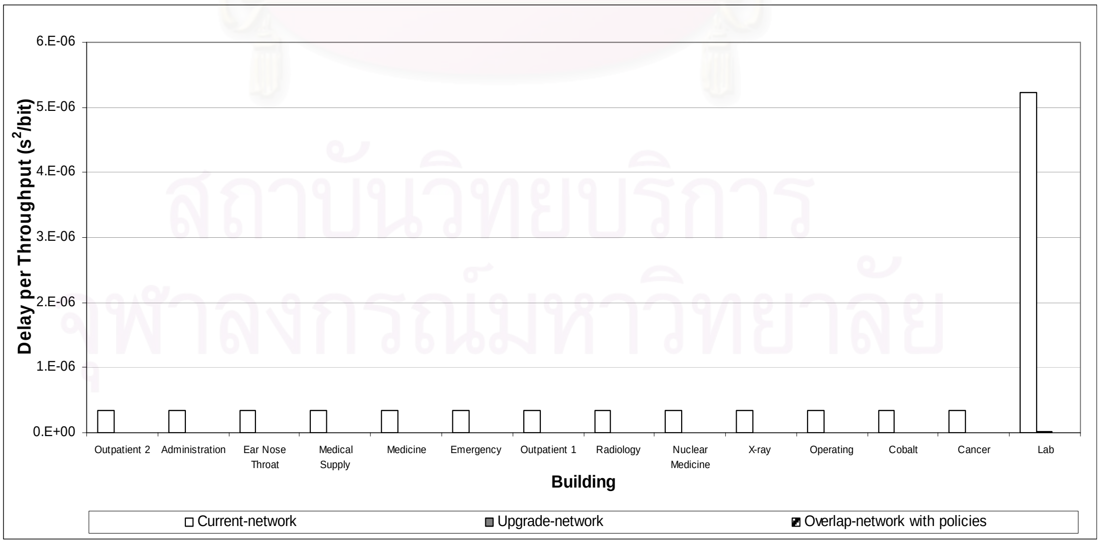

Figure 4.35: The average delay per throughput of each building in real architectures where the ratio of offered loads to the maximum load stands at 1:1

• *Ratio 5:4*

The comparison of the delay per throughput in each building of real architectures, where the ratios of offered load served for the main task in the hospital to the maximum load stand at 5:4, is shown in Figure 4.36. According to the previous result, the delay per throughput from Current-network and Upgrade-network is continually increased from the first building to the last one due to FIFO of the queue types. Since the offered load at this condition is greater than the previous one, the delay per throughput is increased rapidly in the last three buildings of Current-network and Upgrade-network. Moreover, although the delay per throughput in the last three buildings of both models is increased rapidly, this value from Upgrade-network is less than that from Current-network due to the modern technology of the wired network in Upgrade-network. In contrast, this value from Overlap-network with policies is very low and also approaches to that from Upgrade-network, in the highest as well as the middle priority buildings. Due to the fact that it can reserve the short delay time for the higher priority buildings, the delay per throughput increases rapidly in the lowest priority ones.

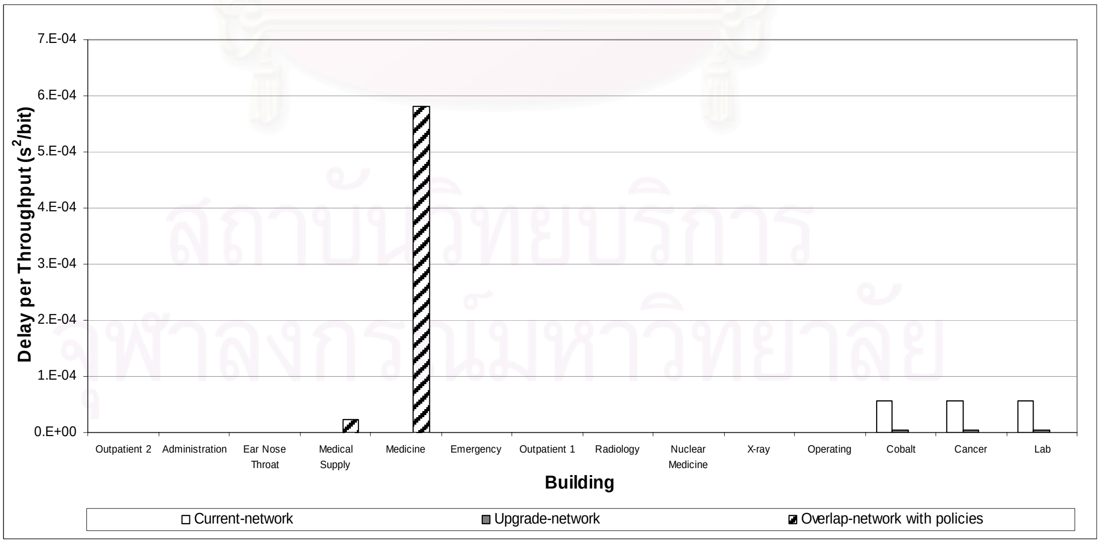

Figure 4.36: The average delay per throughput of each building in real architectures where the ratio of offered loads to the maximum load stands at 5:4

4.2.5 Wi-Fi Throughput

Since Overlap-network with policies has the installation of the wireless technology as well as applying the wireless policy for it, the throughput loss rate from Wi-Fi should be determined in order to illustrate the impact of applying the wireless policy in this model.

The comparison of the average throughput loss rate of each wireless flow type in Overlap-network with policies is shown in Figure 4.37. The result has shown that the throughput loss rate of each flow type in the wireless network is consistent with the applied wireless policy. Thus, there is no throughput loss in the flow of patient information for doctors, which is the highest priority flow in the wireless policy. Likewise, there is a little bit loss in the flow of Internet services for doctors, which is the middle priority flow. Consequently, it can be noticed that applying this wireless policy can efficiently support a transmission of significant applications via Wi-Fi, without loss. Even though the throughput loss rate is increased in the flow of Internet services for patients, this value is low. So, patients can fluently surf the Internet or even access e-services while they are waiting for diagnosis.

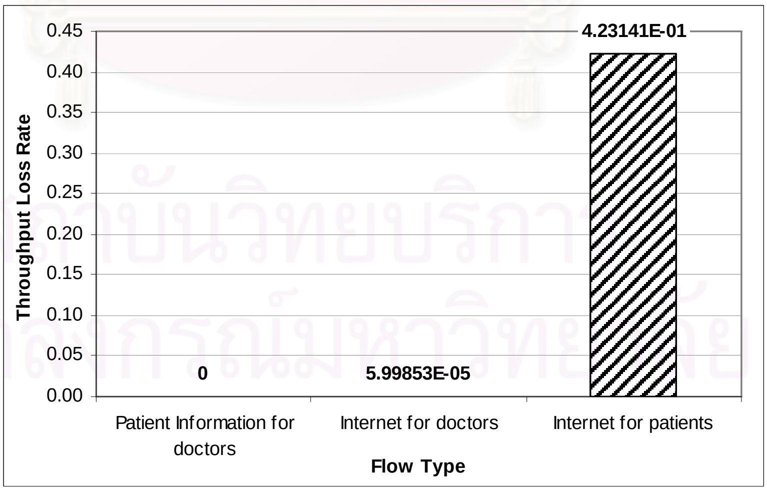

Figure 4.37: The average loss rate of each wireless flow type in Overlap-network with policies when the offered loads of Patient Information for doctors, the Internet for doctors, and the Internet for patients are 20 Mbps, 130 Mbps, and 130 Mbps, respectively

4.2.6 Wi-Fi Delay

For Wi-Fi, the policy was setting up by considering the objectives and user types. Thus, the delay per throughput from Wi-Fi of Overlap-network with policies should be determined in this experiment in order to demonstrate the impact of the wireless policy on each flow type.

The comparison of the average delay per throughput of each wireless flow type in Overlap-network with policies is shown in Figure 4.38. For this result, it has shown that the delay per throughput of each flow type corresponds to the applied wireless policy. Thus, this value is very low in the flow of patient information for doctors as well as the flow of the Internet for doctors. Consequently, the efficient transmission of significant applications via Wi-Fi can be obtained the very short delay time. Although the delay per throughput from the flow of the Internet for patients has increased, it is very low so that patients can surf the Internet, access e-services, or even access multimedia web sites efficiently.

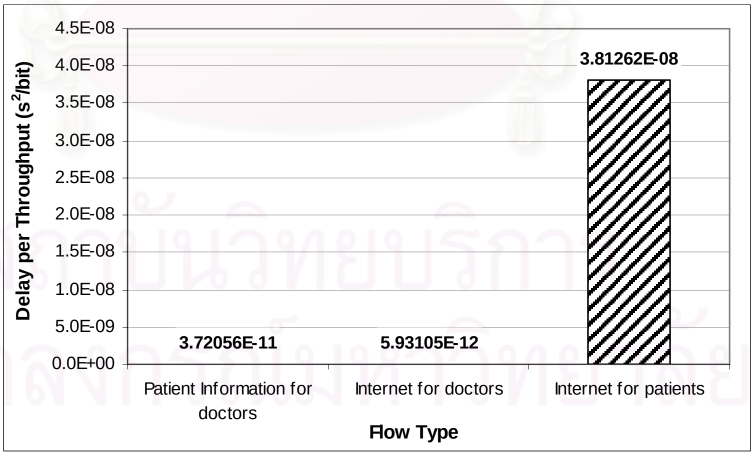

Figure 4.38: The average delay per throughput of each wireless flow type in Overlap-network with policies when the offered loads of Patient Information for doctors, the Internet for doctors, and the Internet for patients are 20 Mbps, 130 Mbps, and 130 Mbps, respectively

CHAPTER V

DISCUSSION AND CONCLUSIONS

In this chapter, all experimental results will be discussed in Section 5.1, and conclusions will be drawn in Section 5.2, followed by suggesting the future work for this Thesis in Section 5.3.

5.1 Discussion

In simulated architectures, overall throughput loss rates from the wired and Wi-Fi networks model, and the wired and Wi-Fi networks with policies model are less than that from the wired network model, and the wired network with policy model. In addition, due to the wired policy, the wired and Wi-Fi networks with policies model can efficiently reserve very short delay times for significant departments. As well, applying the wireless policy to the wired and Wi-Fi networks with policies model can obtain a very low throughput loss rate and delay per throughput in transmission of significant applications via Wi-Fi. Thus, it can be implied that the wired and Wi-Fi networks with policies would be the best solution for enhancing network performance in the Medicare system.

Consequently, this solution will be adjusted and provided for designing a network architecture and suitable network policy for a real architecture. Therefore, Overlap-network with policies was proposed in this Thesis. When comparing this model with Current-network and Upgrade-network, the result has shown that Overlap-network with policies can achieve the minimum overall throughput loss rate. Moreover, even though it is in the congestion situation, it efficiently reserves a very low value of the throughput loss rate as well as the delay per throughput in the highest and the middle priority buildings, which are the significant buildings that the throughput loss and the long delay of incoming messages should be avoided. Furthermore, applying the wireless policy to this model can sustain transmission of the flow of the patient information for doctors and the Internet for doctors with the very low of the throughput loss rate and the delay per throughput. Consequently, Overlap-network with policies can be an efficient solution for improving network performance in the Medicare system with cost-effectiveness, while Current-network cannot support increasing network utilization, and even though Upgrade-network can be obtained better performance in some aspects, it has no policy applied to significant application and the investment causes a large amount of time and cost for its implementation.

Additionally, there are many researches, such as [2], and [3], support installation of the wireless over the cabling systems, since the experimental results of these papers have illustrated that this implementation enhances the network performance with cost-effectiveness. Besides, the results of this Thesis are consistent with these researches that Overlap-network with policies can also improve network performance of the Medicare system. Unfortunately, the previous researches have not applied any appropriated policies to their overlapping networks.

Furthermore, although there are some researches, such as [7], [8], and [9], mentioned about policy for the heterogeneous network, they do not emphasize on the Medicare system, despite the fact that this system is very important and provided medical services to patients directly. Consequently, researches applying policy on the Medicare system is rare, especially in Thailand. Therefore, this research has successfully proved that Overlap-network with policies is the efficient solution with cost-effectiveness on the network management policy for overlapping between cabling and wireless networks in the Medicare system.

5.2 Conclusions

From the results, it has shown that an appropriate management of transmitted applications through network policy as well as determining of resource allocation by installing a wireless network over the original wired network can efficiently enhance performance by relieving the congestion and delay problems, and at the same time it also supports portability, scalability, implementation, and maintenance with cost-effectiveness. Thus, Overlap-network with policies is an efficient solution for enhancing performance of this Medicare system. Additionally, prioritization through the policies can efficient reserve very low throughput loss rates and the delay per throughput for significant applications transmitted via wired and Wi-Fi. This management is necessary for the Medicare system, because transmitted applications in this system can be significant in vital. Since the policy is sets of high-level statements and rules about how network should perform, it is flexible and easy to be implemented when compared to other performance mechanisms. Especially, both policy and prioritization can be changeable in the future, if the objective is changed.

5.3 Future work

In this experiment, the preliminary study on impact of the applied policies at various conditions is determined on the network performance of each model in the specified offered load. Thus, it can be defined this implementation as the fixed algorithm. Therefore, the dynamic algorithm should be further study for improving this system. So, the policies can automatically adjust according to the network conditions.

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